Environment Canada Environnement Canada

Analysis of Current and Historical Surface Water Monitoring Programs and Activities in the Athabasca Oil Sands Area, to 2011

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Canada

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INTRODUCTION

90 DAY ACTION PLAN ON SURFACE WATER QUALITY MONITORING DESIGN IN THE OIL SANDS

PHASE 1

On 16 December, 2010 a Federal Review Panel tabled its report (Dowdeswell *et al.* 2010) to the federal Environment Minister. The report included the review and identification of key shortcomings and knowledge gaps in the current water quality and quantity monitoring programs in the lower Athabasca River system and provided recommendations on action needed to develop and implement a "World-Class" monitoring program. The Minister of Environment subsequently committed Environment Canada to take action on the panel's recommendations, and work in partnership with the Government of Alberta to develop a preliminary design for a water quality monitoring program in the oil sands region, focussing on water chemistry and physics aspects. The design for a water quality monitoring program in the surface-mineable oil sands area was the first step (Phase 1). Subsequent steps (Phase 2) would expand the monitoring design. The geographic scope of Phase 1 focussed on the mainstem of the lower Athabasca River basin between Fort McMurray and the Athabasca Delta, including major tributaries. The Lower Athabasca Water Quality Monitoring Plan – Phase 1 (Environment Canada and Alberta Environment 2011) was released in March 2011.

COMPONENT 2

Component 2 of the Phase 1 water quality monitoring design is a bibliographic compilation of water-related monitoring programs and activities prior to the implementation of the Integrated Monitoring Plan for the Oil Sands (Environment Canada and Alberta Environment 2011c). It comprises an information table of parameters sampled by the most relevant ongoing and historical programs and activities, annotated abstracts and descriptions of relevant programs and studies, notes on particularly relevant organizations, and maps of monitoring locations and other information, up to July 2011. This document is a bibliographic tool for locating sources of water quality information, providing a general roadmap to "who has measured what, when, and where?". It was not intended to collect or contain data.

The terms of reference included: "current and historical Government of Canada water quality and quantity monitoring programs (such as those of Environment Canada, Pulp and Paper Environmental Effects Monitoring, and Parks Canada Agency), the Province of Alberta and relevant stakeholder monitoring organizations (such as RAMP), and the most relevant University-based studies on surface water quality" (chemical and physical). Current programs (to 2011) were reviewed, inorganic and organic chemical constituents/contaminants were assessed, and toxic compounds identified by several sources were examined. Some analytical challenges and constraints that should be taken into consideration were included.

In addition, a preliminary analysis of the current permit- and regulatory-related surface water quality monitoring in the Lower Athabasca oil sand region being performed by industry was conducted. This analysis was intended to identify the core surface and groundwater water quality parameters and effects-based endpoints that must be monitored by industry to meet licensing/permitting requirements. To accomplish that goal, information from Alberta Environment was requested. Further information, such as the specifics of sewage outfalls, remains to be gathered and collated.

As Phase 1 concentrated on the physical and chemical aspects of water quality, this report is restricted to physical and chemical monitoring and studies. The subsequent Phase 2 Geographic Expansion topic included biological information as well as the physical and chemical. The Geographic Expansion section also included a Component 2 compilation (Lindeman *et al.*, 2011).

Long-term monitoring is essential to understand aquatic ecosystems and to determine trends over time. Water quality in the environment is the result of causal mechanisms including the activities of humans and natural hydrologic, biological and geochemical cycles. Water quality conditions over geographic areas are the function of these natural and anthropogenic processes, which interact in a complex manner in both time and space. As water quality science has evolved, it has become evident that water quality monitoring must be treated as a statistical sampling process (Sanders *et al.*, 1983).

Water quality monitoring in the oil sands region can and should be informed by the current and historic monitoring, focussed studies, and research activities that have produced data and information over time. Sources and locations of this information are many and disparate. Data mining for historical information is an ongoing process. In this document, major activities and programs as of July 2011, prior to the Integrated Plan implementation, then historical activities are summarized. Certain organizations that are relevant to activities in the Athabasca oil sands area are also noted.

The most important tool in this document is Appendix 1, which includes specific information on parameters sampled by the major monitoring programs and other activities in the oil sands region up to July 2011. Some of the studies excluded from Appendix 1, particularly historic documents, are included in the text if they may provide potentially useful information or sources of data on specific topics. Annotated abstracts of these, as well as all studies in Appendix 1, are included under the appropriate subheading.

SECTION 1: COMPILATION OF MONITORING AND ACTIVITIES

1A: CURRENT MONITORING AND FOCUSSED STUDIES

1A1: CURRENT LONG-TERM WATER QUALITY AND QUANTITY MONITORING

1A1.1: Alberta Environment

Surface water quality assessments have been conducted on lakes and rivers in Alberta since the 1940s. Initially, the work focused on basic inventories to describe the state of fisheries and water resources in Alberta.

Following the creation of Alberta Environment (AENV) and the development of provincial legislation for regulating point-source discharges in the 1970s, field studies expanded to include non-point source issues associated with logging, agriculture, mining, urban runoff and atmospheric deposition (Alberta Ministry of Environment Surface Water Quality Program website).

Water quality monitoring on the Athabasca River began as early as 1955 for some variables, but regular sampling for most parameters was not implemented until at least 1960. Initially, sampling efforts were limited to a single station at the Town of Athabasca. In 1977, a second site was established at Old Fort, 200 kilometres downstream of Fort McMurray. Until 1987, long term water quality sampling was performed by what would eventually become Environment Canada. In 1987, responsibilities for sampling in areas inside Alberta's borders shifted to Alberta Environment (Alberta Environment 2011)

At the Old Fort Long Term River Network (LTRN) site, data are available from 1968, but the station shifts from the Embarras airport (~15 km downstream of the 27th baseline) to 25 km further downstream at Old Fort around 1990, where it has remained since (except in winter). For the Hinton (Old Entrance) LTRN, there are 311 samples from 1956 through 1996 when the site moved slightly upstream and then further upstream again in 1999 and again in 2004. There are a total of around 530 samples from that general location dating from 1956, and even more if the Athabasca River downstream of Hinton is considered as well (Rod Hazewinkel, pers. comm.).

In more recent years, two additional sampling stations were created on the Athabasca River as a means of more effectively monitoring specific anthropogenic pressures, including forestry, pulp production, and resource extraction. These sites, situated upstream of both Hinton and Fort McMurray, were incorporated into the network in 1999 and 2002, respectively.

Alberta Environment long-term monitoring sites are indicated on Figure 3, Figure 4 and Figure 5. Figure 3 sets regional context, at "zoom level 1", which is the Athabasca Basin within Alberta. Figure 4 shows the lower Athabasca Basin area, from just south of Stony Mountain Wildland Provincial Park to the southern portion of Wood Buffalo National Park. Figure 5 is at "zoom level 3," which is the reach of the Athabasca River from Fort McMurray to just south of Wood Buffalo National Park.

As far as can be determined, the Alberta Environment database contains all data (including many AOSERP, NRBS and NREI data) from when the database, called NAQUADAT, was jointly developed with Environment Canada (Rod Hazewinkel, pers. comm.). Parameters for the AENV long-term river network monitoring sites are listed in Appendix 1.

1A1.2: Environment Canada

1A1.2.1: Water Quality

In cases where rivers flow from one province to the next, trans-boundary agreements are in place to ensure that adequate water quality and quantity are maintained. Examples of trans-boundary agreements include the Prairie Provinces Water Board (PPWB) Master Agreement on Apportionment (for east-flowing waters) and the Mackenzie River Basin Transboundary Waters Master Agreement (MRBB) for the Mackenzie and its tributaries (Alberta Ministry of Environment Surface Water Quality Program website). Environment Canada typically monitors water quality on trans-boundary rivers at provincial boundary reaches, in some cases in partnership with Alberta Environment. Environment Canada also monitors water quality in a number of national parks, including the Athabasca River headwaters in Jasper National Park, and sites on the lower Athabasca and lower Peace Rivers, as well as the Slave River near the boundaries of Wood Buffalo National Park.

Prior to 1987, long term monitoring in Alberta was carried out by what would eventually become Environment Canada (Alberta Environment 2011). Changes in the precise locations of sampling stations and lack of accurate georeferencing from the early years causes some difficulty in assessing complete periods of record. However, sampling at some long-term sites has been relatively consistent; for example, Environment Canada database records indicate that sampling on the Athabasca River at the town of Athabasca was conducted from 1961 to 1986, with a total of 305 samples in the database.

Figure 3, Figure 4 and Figure 5 show the long-term water quality monitoring sites operated by Alberta Environment and Environment Canada in the Athabasca Basin. Parameter information is included in Appendix 1.

1A1.2.2: Water Quantity

Water quantity (i.e., lake level and river level/discharge) is monitored in Alberta through a network of hydrometric stations operated by Water Survey of Canada (Environment Canada), plus a small network of hydrometric stations operated by Alberta Environment. Data from both sources is published within the Environment Canada, Water Survey of Canada HYDAT hydrologic monitoring database (Rick Pickering, Alberta Environment, pers. comm.) Historic sediment monitoring at Water Survey of Canada hydrometric sites is described in subsection 1.B.5. Water quantity data are essential when assessing chemical fluxes and loading. Climate information (e.g., precipitation and air temperature) are currently, and have been historically monitored at a select few sites. These data provide useful information for assessing first-order drivers of water quantity and quality. An example is the use of snow water equivalence of spring snowpack to calculate contaminant loading.

Figures 6, 7 and 8 indicate the location of Water Survey of Canada water quantity monitoring stations in the Athabasca River basin. Alberta Environment and Environment Canada climate stations, and Alberta Environment snowpack measurement sites are also included. Long-term precipitation data (e.g., snowpack depth and snow water equivalence and rainfall) are useful to compare current year precipitation to historical context (above/below average) and may also be used to spatially interpolate precipitation data and calculate loadings for the region. These maps are also based on the three "zoom levels" as indicated above. The first level is for geographic reference, the second covers the oil sands area, and the third encompasses mineable oil sands area reaches/basin areas.

1A1.2.3: Federal Stream Gauging in Canada

The Federal Department of the Interior started its first systematic stream gauges in 1897 in southern Alberta and southern Saskatchewan to help determine if there was adequate water for irrigation purposes and to encourage new development and western expansion. The success of this early work led to the establishment of the Water Resources Branch in 1908 as approved through a vote in the parliament of Canada under the Department of the Interior. During the late 1960's the hydrometric activities under the Water Resources Branch adopted the name Water Survey of Canada and has been operating under that name to present day. Currently, the Water Survey of Canada operates over 2300 stream gauges across Canada in partnership with the provinces and territories under a cost-share arrangement established in 1975.

Streamflow estimation generally involves 4 steps.

- Measuring stream stage—obtaining a continuous record of stage—the height of the water surface at a location along a stream or river above an arbitrary reference plane.
- Recording the time coincident with the stage observation.
- Establishing a rating between observed stage and measured volumetric discharge. The discharge measurement is determined by velocity/area method.
- Converting stage information to streamflow information—using the stage-discharge relation developed in step 3 to convert the measured stage into estimates of streamflow or discharge as daily means, annual totals, and annual extremes.

Stream gauging involves obtaining a record of time varying stage, making periodic discharge measurements, establishing and maintaining a relation between the stage and discharge, and applying the stage-discharge relation to the stage record to obtain a discharge value. The Water Survey has provided Canada with consistent, reliable streamflow information for over 100 years.

There is a national standardized approach to data collection, processing, archiving, and distribution for the hydrometric data collected under the cost-shared program.

Hydrometric stations are located on lakes, rivers and streams of many sizes, ranging from drainage basins as small as a few hundred km^2 to large watersheds like the Mackenzie Basin (1,680,000 km^2). Data for the current federal-provincial network of 2931 gauging sites (of which WSC operates approximately 2300) are stored along with those for 5416 discontinued sites in the national Water Survey of Canada HYDAT database and made readily available through various media, including a public web page:

http://www.ec.gc.ca/rhc-wsc/

The cost for the current hydrometric program operations is based on formal cost-share agreements where full cost recovery for station operations is agreed to by EC and the Provinces/Territories across Canada. All stations of provincial interest that are operated by WSC are fully cost-recovered. Stations of federal interest are paid for by EC and stations of joint interest are shared on a 50/50 split. Costs associated with stations of federal interest, but operated by the province, are funded by EC. As an example, water level gauges in the Peace-Athabasca Delta region are operated by the province of Alberta, but paid for by EC. These partnership agreements allow for full cost recovery for either party, and the operator is agreed to be the one best positioned to collect the information.

The current and historic network of federal and provincial stations for the Athabasca drainage basin is shown in Figure 9.

The breakdown of stations is as follows:

- Historical and active flow stations in the Athabasca Basin: 165
- Active flow stations: 72

- Active continuous flow stations: 21
- Active continuous flow sites in the vicinity of the oil sands: 2
- Active continuous flow sites downstream of mining area: 0

For the purposes of this description, the drainage area of the Athabasca River basin (excluding the Athabasca Delta and Lake Athabasca) will be limited to the Embarras Airport station gauge (currently inactive) where the drainage basin is estimated from WSC records at 155,000 km^2. The Embarras airport location represents the furthest downstream point of gauging before entering the Wood Buffalo National Park. This station and the drainage area it represents are used as the end-point for further analysis. Also, since the focus here is on analysis of the hydrometric network in and around the oil sands region, analysis is limited to gauges starting at the Town of Athabasca and downstream to the discontinued site at Embarras airport. The region is divided into 3 reaches (principle regions with two main river reaches). The area upstream of the Town of Athabasca is the upper region of the basin and is not considered. The region between the Town of Athabasca and the town of Fort McMurray is referred to here as the middle reach. The region downstream of Fort McMurray and upstream of the discontinued Embarras gauge is referred to here as the lower reach.
The list of hydrometric stations active between the Town of Athabasca and the former hydrometric site at Embarrass Airport in 2009 is presented in Table 1. It is important to understand that the Embarras station is no longer active and only serves as a geographic reference point.

Table 1: List of active stations (with the exception of Embarras Airport) and respective drainage areas that each gauge represents.

Station	Station Name	Hydat Status	Prov	Latitude Degrees	Longitude Degrees	Drainage Area km	Years	From	To	Sed	Oper Sched
Tributary Stations between the town of Athabasca and Fort McMurray											
*07CA003	FLAT CREEK NEAR BOYLE	Active	AB	54.5873	-112.907	183.6	43	1919	2009	FALSE	Seasonal
07CA005	PINE CREEK NEAR GRASSLAND	Active	AB	54.8204	-112.778	1456.4	44	1966	2009	TRUE	Miscellaneous
07CA006	WANDERING RIVER NEAR WANDERING RIVER	Active	AB	55.1995	-112.4674	1,120.40	39	1971	2009	FALSE	Seasonal
*07CA08	BABETTE CREEK NEAR COLINTON	Active	AB	54.6525	-113.079	219.3	32	1978	2009	FALSE	Seasonal
*07CA012	LOGAN RIVER NEAR THE MOUTH	Active	AB	55.1724	-111.7248	425.00	26	1984	2009	FALSE	Seasonal
07CA013	OWL RIVER BELOW PICHE RIVER	Active	AB	55.0109	-111.8563	3,078.30	26	1984	2009	FALSE	Seasonal
07CB002	HOUSE RIVER AT HIGHWAY NO. 63	Active	AB	55.6425	-112.1527	780.60	28	1982	2009	FALSE	Seasonal
07CD001	CLEARWATER RIVER AT DRAPER	Active	AB	56.6853	-111.2554	30,791.60	56	1930	2009	TRUE	Seasonal
07CD004	HANGINGSTONE RIVER AT FORT MCMURRAY	Active	AB	56.7090	-111.3564	962.00	45	1965	2009	TRUE	Seasonal
*07CE002	CHRISTINA RIVER NEAR CHARD	Active	AB	55.8372	-110.8690	4,862.90	28	1982	2009	FALSE	Seasonal
*07CE003	PONY CREEK NEAR CHARD	Active	AB	55.8698	-110.9173	279.20	28	1982	2009	FALSE	Seasonal
	Total Area Drained					**38,189.30**					
Tributary Stations between Fort McMurray and Embarras Airport											
07DA006	STEEPBANK RIVER NEAR FORT MCMURRAY	Active	AB	56.9995	-111.4068	1,319.85	38	1972	2009	TRUE	Seasonal
07DA008	MUSKEG RIVER NEAR FORT MACKAY	Active	AB	57.1912	-111.5701	1,457.00	36	1974	2009	TRUE	Seasonal
07DA018	BEAVER RIVER ABOVE SYNCRUDE	Active	AB	56.9453	-111.5663	164.80	35	1975	2009	TRUE	Seasonal
07DB001	MACKAY RIVER NEAR FORT MACKAY	Active	AB	57.2104	-111.6951	5,569.30	38	1972	2009	TRUE	Seasonal
07DC001	FIREBAG RIVER NEAR THE MOUTH	Active	AB	57.6511	-111.2026	5,987.60	39	1971	2009	TRUE	Seasonal
	Total Area Drained					**14,498.55**					
Main Stem station from the town of Athabasca to Embarras Airport											

Station	Station Name	Hydat Status	Prov	Latitude Degrees	Longitude Degrees	Drainage Area km	Years	From	To	Sed	Oper Sched
07BE001	ATHABASCA RIVER AT ATHABASCA	Active	AB	54.7220	-113.2880	74,602.30	90	1913	2008	FALSE	Continuous
07DA001	ATHABASCA RIVER BELOW FORT MCMURRAY	Active	AB	56.7804	-111.4022	132,585.00	52	1957	2008	TRUE	Continuous
07DD001	ATHABASCA RIVER AT EMBARRAS AIRPORT	Discontinued	AB	58.2050	-111.3900	155,000.00	14	1971	1990	TRUE	Seasonal

Drainage Areas	Area	% gauged by Tributaries
Athabasca River at Athabasca	74,602.30	-
Between Athabasca to Fort McMurray	57,982.70	65.9%
Between Fort McMurray to Embarras Airport	22,415.00	64.7%
Athabasca River at Embarras Airport	155,000.00	

***denotes tributary basin upstream of a currently active WSC gauge**

As Table 1 indicates, there are only 2 active stations running continuously throughout the year for the region in question. All other stations are seasonal (summer only).

The middle reach is the region downstream of the Town of Athabasca and upstream of the Fort McMurray station. This reach represents about 37% of the entire basin area. In this middle reach there are 6 seasonal stations that contribute directly to the main-stem of the Athabasca River, with the largest being the Clearwater station at Draper. The drainage area above the Clearwater gauge represents about 20% of the total Athabasca basin to Fort McMurray; and represents 53% of the total basin area between the Athabasca town site and city of Fort McMurray. The remaining gauges on the list monitor basins that are located upstream of another tributary and whose flow would be captured by the downstream gauge. When adding all the gauged area for the entire middle reach, about 65% of the reach is gauged by seasonal (summer only) WSC gauges.

Below Fort McMurray, the total tributary area being monitored and flowing into the lower reach is about 65 % of the total drainage into that second reach. Again, all stations here are seasonal.

1A1.3: Regional Aquatics Monitoring Program (RAMP)

A stakeholder-based organization, the Regional Aquatics Monitoring Program (RAMP) performs monitoring in the oil sands area. RAMP is intended to determine, evaluate, and communicate the state of the aquatic environment and any changes that may result from cumulative resource development within the Regional Municipality of Wood Buffalo (RAMP website). Figure 10 shows the locations of RAMP water quality monitoring sites in the Lower Athabasca and surface-mineable oil sands region.

RAMP was initiated in 1997 as an industry-funded, multi-stakeholder initiative that monitors aquatic environments in the oil sands region (RAMP, 2010). The program is funded by industry, and implemented by consultants who perform the monitoring, analyze the data, and submit annual reports. It is governed by the RAMP Steering Committee which includes industry representatives, provincial, and federal agencies (RAMP, 2010). The annual monitoring program is designed each year by the RAMP Technical Subcommittee which also evaluates the findings each year, as presented in the draft annual report. RAMP Technical Subcommittee meets approximately three times a year to design the program which will be implemented about 18 months later, in accordance with the planning cycle of the funders. At that meeting the fall sampling program and initial findings for the current calendar year are discussed, and the committee members review the draft annual report for the previous calendar year.

Certain general principles govern the RAMP Technical design. RAMP endeavours to collect pre-impact data at sites located downstream of planned developments and maintains sites upstream (baseline) and downstream (test) of planned and existing development. Once development is initiated within a given watershed, the sites located downstream are considered to be potentially impacted and are no longer considered reference sites. Monitoring continues at these sites, typically at a reduced annual frequency. Comparisons are drawn between pre- and post-impact conditions for a given site, among sites along a given stream or river, and between potentially impacted (test) sites and groups (clusters) of presumed reference sites. The RAMP Technical design includes three years of monitoring prior to the implementation of a development activity and at least three years of monitoring after that activity is initiated; such water quality monitoring is conducted four times a year. As new developments are approved, companies seek membership on RAMP and are expected to contribute financially according to the scope and scale of their operation. Only operators of surface mines are required to conduct regional-scale monitoring of aquatic ecosystems, which they are encouraged to do through RAMP or similar regional initiatives. Therefore, although companies using *in situ* (in-ground, not open-pit) technologies produce bitumen at a level approximately equivalent to that of the surface mines, they are under-represented among RAMP members and certain of their potential regional impacts may not be specifically monitored. Several *in situ* companies are members of RAMP. Another consideration in the region is the expanding forestry activity; even in the absence of the oil sands activities, much of this general area was scheduled to be logged. It must be recognized that there are two ongoing disruptions to the landscape; the oil sands developments (open pit, and *in situ*) and an expanding forestry industry.

The RAMP study design is based on sampling outside the immediate development footprint. In undeveloped watersheds, sites are established as upstream and downstream baseline sites. It is recognized that upstream sites can have inherently different water chemistry and biology, including commonly measured benthic populations, from downstream sites. For this reason, inter-site comparisons are drawn on the basis of similarity with regional reference groups in addition to longitudinal and temporal comparisons. During RAMP Technical Subcommittee meetings, these sites are selected and placed in a general area with the specific location selected in the field. Helicopter access and other access considerations determine exactly where samples are collected. With the growth of the industry it is increasingly difficult to have a broad picture of the expanding development (Marlene Evans, Environment Canada, pers. comm.).

In addition to RAMP monitoring, on-site monitoring is conducted by the companies within the development areas (see Section 2D2). Other than for the reporting of water withdrawals and water releases from the development area, this monitoring is not considered by RAMP in its study design (which is upstream and downstream of this development area), nor in RAMP's reporting. Water releases are reported to Alberta Environment (see Section 2D2).

RAMP conducts flow measurements at WSC hydrometric stations during winter and operates some of its own hydrometric stations, in some cases taking measurements at deactivated Water Survey of Canada stations. RAMP also has some climate stations and performs snowpack measurements (RAMP, 2010). These are indicated on Figure 11.

It is important to note that RAMP streamflow data are not considered a Water Survey of Canada data contribution because there has not been an evaluation by WSC of the methods used, despite repeated requests by WSC staff in the past to audit the procedures used by RAMP. RAMP uses WSC "real-time" water level data in the winter for rating curves and to estimate flow. WSC has an agreement to fix any data-logger if the data-stream goes down. It should also be noted that because WSC does not publish these RAMP data, WSC does not do level corrections within the winter period and level information may drift and have an impact on the rating curves being developed by RAMP. WSC resets the level in the spring, when personnel resume measurements. In short, there has not been a formal QA/QC on the RAMP hydrometric data (Greg McCulloch and Al Pietroniro, Water Survey of Canada, pers. comm.).

RAMP also assesses sediment quality. A range of compounds are measured to characterize sediment quality, particle size, carbon content, target and alkylated polycyclic aromatic hydrocarbons (PAHs), total hydrocarbons, and metals. Sub-lethal bioassay tests also are conducted to assess potential toxicity related to chronic exposure of different aquatic organisms to sediments from selected stations (RAMP, 2010). RAMP sediment sampling is shown on Figures 12 and 13.

1A2: MAJOR FOCUSSED STUDIES AND RESEARCH

1A2.1: Water Focussed Studies

1A2.1.1: Alberta Environment Comprehensive Contaminant Load study.

The potential for increased contaminant loading and the cumulative effects from contaminants were the subject of enhanced scrutiny and concern in 2006, when two Joint Panel Hearings on new oil sands developments were held. The greatest scrutiny was directed at the accumulation of metals – particularly arsenic and mercury, as well as carcinogenic organic compounds – in downstream environments and in the country foods of Aboriginal peoples. Oil sands development has the potential to enhance background exposure. The Comprehensive Contaminant Load (CCL) study will build on previous work and will provide an improved understanding of contaminant emissions, transport and fate and potential impacts to the environment in the oil sands region of Alberta. The study seeks to identify and quantify the sources of contaminants in the lower Athabasca River and to quantify the transport and accumulation of these contaminants throughout the region and into the Peace-Athabasca Delta (PAD) and western Lake Athabasca. The study is intended to complement the Regional Aquatics Monitoring Program (RAMP), build on previous research conducted by the provincial and federal governments (including Gummer *et al.*, 2000, Brua *et al.*, 2004, Gummer *et al.*, 2006, McMaster *et al.*, 2006) and partners, and result in an improved monitoring program for the Lower Athabasca River area, including western Lake Athabasca and the Fort Chipewyan area (Government of Alberta 2011).

The study is organized and described based on sources, pathways, and expected fate of contaminants. Ongoing research on air includes tailings pond emissions monitoring; monitoring of contaminant deposition in the snow pack; characterizing airborne contaminants in the context of source attribution; inventory of emissions sources and enhanced ambient air quality monitoring. Extensive water quality, seepage and runoff data are available. The enhanced program for additional data collection includes more frequent Athabasca River and tributary sampling for PAHs, naphthenic acids and metals, and metal sampling in acid sensitive lakes. The temporal variability and transport of contaminants is addressed in the study through core sampling of Lake Athabasca and the "Sharkbite" Lakes. The connectivity between groundwater and the Athabasca River is another pathway for contaminants to enter surface waters. This pathway is assessed using organic tracers and stable isotopes in contaminant seepage to aid in source identification. Finally, the integration of contaminants across all media is proposed through human health risk assessment and a study on aquatic ecosystem health (Government of Alberta 2011).

Water quality sites of the Comprehensive Contaminant Load Study are indicated in Figure 14. Parameters are listed in Appendix 1.

The data and information developed by the Comprehensive Contaminant Loading (CCL) Study will be critical in informing further work on water quality monitoring design. The CCL Study end date is 2012, and results from this initiative will inform AENV in updating and changing Environmental Protection and Enhancement Act (EPEA) approval monitoring requirements.

1A2.1.2: Muskeg River Water Management Framework

The Muskeg River watershed is within the area of surface-mineable oil sands deposits. Three oil sands mines, an *in situ* facility and a limestone quarry currently operate within the watershed, and substantial expansion of these and other oil sands mines is planned or in progress. The mining activities could disturb more than 60% of the watershed and a proposal to mine through the Muskeg River channel is being considered. There are concerns that the cumulative effects of these developments could alter constituent loads to the Athabasca River. In response, the Muskeg River Management Framework was developed (Alberta Environment 2008).

The Muskeg River Management Framework (MRMF) for Water Quantity and Quality was completed and released in June 2008 (Alberta Environment 2008). One of its recommendations was the development of an integrated monitoring plan for the Muskeg River watershed, with the cooperation of industry stakeholders. The plan coordinates off-lease monitoring activities that would otherwise be conducted by individual companies. This coordination provides an effective and efficient means to compare the status of water quality at any site, supports an adaptive approach to water quality management, and vastly improves the scientific rigor by the application of an effects-based approach to monitoring. As part of this coordination, all water samples are collected within the same period of time using the same laboratory analytical protocols. The Muskeg River Management Framework (MRMF) defines criteria for evaluating water quantity and quality. Observed conditions are compared against established limits that were developed specifically for the Muskeg River watershed, although further refinement of these limits may follow implementation of the Lower Athabasca Regional Plan. These limits were based on data collected within the watershed, as well as additional information on streamflow, water quality, requirements of the aquatic ecosystem, and standards and limits compiled from other jurisdictions. The integrated monitoring program is a partial fulfillment of the monitoring requirements under existing Environmental Protection and Enhancement Act approvals (see Section 2D2) – specifically monitoring of the receiving water body upstream and downstream of a project site. The main purpose of the integrated monitoring program is to support the recommendations of the MRMF that specify targets and limits for water quality and water quantity. The integrated monitoring program complements and builds on pre-existing monitoring programs, but does not replace specific monitoring programs associated with fish toxicity, benthic macroinvertebrate, and sediment monitoring presently conducted by the Regional Aquatics Monitoring Program (RAMP) and by individual approval holders (Alberta Environment 2009).

The Muskeg River annual monitoring report is intended to meet the requirement in the MRMF for reporting and communication of monitoring results conducted through the integrated monitoring program. The report provides performance assessment to enable the implementation of management actions that are consistent with the triggers provided in the MRMF (Alberta Environment 2009).

Effectively, Alberta Environment has taken on a substantive portion of the monitoring in the Muskeg River watershed. This provides comprehensive and consistent monitoring and allows for consolidation of data collected for application to the requirements of the Management Framework. Extensive monitoring also occurs in this basin via RAMP, and requirements under the companies' Fisheries Act authorizations (fish monitoring). The companies still conduct all of the settling pond and pond discharge monitoring required under their EPEA operating approvals, which is an essential component of water management in the Muskeg River basin.

Figure 14 indicates the locations of the Muskeg River basin monitoring sites under this Framework. Further details on parameters sampled can be found in Appendix 1.

1A2.1.3: Environment Canada Hydrological-Ecological Study

Following-up on the issue of decreasing trends in water availability highlighted in a paper by Schindler & Donahue (2006) entitled "An impending water crisis in Canada's western prairie provinces", Environment Canada is currently engaged in scientific research activities focusing on assessing the issues of water availability/water balance and the sustainability of streamflow to the lower Athabasca River and Delta. In particular, the potential effects of rapidly increasing upstream development and climate variability/change on seasonal streamflows and on eco-hydrologically relevant hydrograph parameters (e.g., quantity and timing of annual peak and low flows) are being investigated. Streamflow along the mainstem of, and tributaries to, the Athabasca River are being examined to determine if reported decreasing flow trends are discernable in the alpine, foothill, and lowland regions of the watershed, and if so, to establish what are the causal factors driving the observed trends (e.g., large-scale climate signals, land-use change, water uses, etc) (Dan Peters, Environment Canada, pers. comm.). The Federal Government has responsibilities related to transboundary water and flow through National Parks and First Nation Land located downstream of the Embarras station.

1A2.1.4: Environment Canada groundwater studies

There are concerns that oil sands production may result in seepage of contaminated groundwater to surface waters. In particular, seepage of groundwater that has been affected by process water at tailings facilities, including tailings ponds, is of great interest. The Federal Government has responsibilities related to potential impacts of such contaminated groundwater on stream water quality and the health of aquatic biota, and in determining if and when Fisheries Act infractions are occurring.

1. The Surface Water/Groundwater Interaction Study

This study investigates whether process-affected water from oil sands tailings impoundments in Alberta can be directly detected in groundwater discharging to the Athabasca River and its tributaries.

To focus on groundwater/surface water interaction, most groundwater samples for this study are being collected from shallow depths (less than 2 meters) beneath streams using temporary drive-point installations. Some key advantages of this method include the ability to quickly select and access groundwater sampling locations, no instrumentation is left behind, and the ability to focus on groundwater/surface water interaction in detail.

A consideration of the complexities of the local geology is inherent to this work. Natural springs occur along the Athabasca River and its tributaries; some of these are saline. In collaboration with the University of Calgary and Natural Resources Canada (NRCan), samples of springs along the Athabasca River and its tributaries are being collected, and zones of perched groundwater flow (may be seasonal or episodic, following precipitation events) are also being targeted, as appropriate (see Study 2, below).

Chemicals in the groundwater samples under analysis include inorganic chemicals, metals, selected petroleum hydrocarbons, and naphthenic acids. Stable isotope analyses are being included to probe the sources and processes affecting groundwater, and some of the chemicals found in the groundwater (sulphate, ammonia). There are some preliminary indications of chemical effects of process water on shallow groundwater beneath the Athabasca River near the Suncor 1 tailings facility. Results from this study will enhance groundwater/surface water understanding and available data (Greg Bickerton, Environment Canada, pers. comm.). Sampling locations are indicated on Figure 15. This surface water/groundwater link is also highly complementary to the Alberta Environment Regional Groundwater Monitoring Network.

2. The Perched Groundwater Seeps Study

The seeps study is a field sampling program which aims to identify and characterize potential perched groundwater sources that enter into the Athabasca River directly or via its tributaries. Water samples were collected from a sub-component of the sites (see Figure 15) to assess the geochemical contributions of these groundwater sources. Specific objectives for the study were to:

- Identify and map the location of perched groundwater seeps along the interface of the McMurray Formation and the overlying unconsolidated material along the main-stem of the Athabasca River and tributaries.
- Identify and select sites for water sampling to assess the geochemical nature of these shallow seeps.
- Collect water samples to determine baseline, ambient, undisturbed condition chemistry (major ions and isotopic composition) as well as contributions of potential contaminants to the Athabasca River system. Analysed contaminants included metals, polycyclic aromatic compounds (PACs), and naphthenic acids.
- Obtain estimates of flow rate, if feasible, to use as a means of determining mass flux from these seeps.
- For any significant groundwater sources entering into the receiving waters, collect water samples upstream and downstream to assess influence on chemistry of the surface receiving waters

Parameters measured included temperature, pH, conductivity, dissolved oxygen, discharge, geo-description of seep, major ions, dissolved and total metals, PAHs, fluorescence, naphthenic acids, enriched tritium (as a first-cut screening tool on the age of the water), ammonium, ammonium isotopes, mercury, and bitumen (Malcolm Conly, Environment Canada, pers. comm.). Further details are listed in Appendix 1.

Other Environment Canada research initiatives are underway, however, they are not documented here since their focus is not on surface water quality or quantity.

1A2.2: Major Aerial deposition and related studies

1A2.2.1: Kelly *et al.* PAC and metals studies

The study by Kelly *et al.* (2009) on polycyclic aromatic compounds revealed that the oil sands development has a previously underestimated pathway of contamination. Loading to snowpack from airborne particulates was 11,400 T over 4 months and included 391 kg of PACs. This is equivalent to 600 T of bitumen, while 168 kg of dissolved PACs were also deposited. Dissolved PAC concentrations in tributaries to the Athabasca increased from 0.009 µg/L upstream of oil sands development, measured in both winter and summer, to 0.023 µg/L in winter (approximately 2.5-fold increase) and 0.202 µg/L in summer at the stream mouth sites. In the Athabasca, dissolved PAC concentrations were mostly <0.025 µg/L in winter and 0.030 µg/L in summer, except near oil sands upgrading facilities and tailings ponds in winter (0.031–0.083 µg/L) and downstream of new development in summer (0.063–0.135 µg/L). In the Athabasca and its tributaries, development within the past 2 years was related to elevated dissolved PAC concentrations that were likely toxic to fish embryos. In melted snow, dissolved PAC concentrations were as high as 4.8 µg/L. Thus, spring snowmelt and washout during rain events are important unknowns (Kelly *et al.*, 2009).

A second study by Kelly *et al.* (2010) detected the release of 13 priority pollutants (PPE), defined by US Environmental Protection Agency's Clean Water Act, via air and water, to the Athabasca River and its watershed. Bitumen upgraders and local oil sands development were considered key sources of airborne emissions. In the 2008 snowpack, all PPE except selenium were greater

near oil sands developments than at more remote sites. Additionally, concentrations of mercury, nickel, and thallium in winter and all 13 PPE in summer were greater in tributaries with watersheds more disturbed by development than in less disturbed watersheds. In the Athabasca River during summer, concentrations of all PPE were greater near developed areas than upstream of development. At sites downstream of development and within the Athabasca Delta, concentrations of all PPE except beryllium and selenium remained greater than upstream of development. Concentrations of some PPE at one location in Lake Athabasca near Fort Chipewyan were also greater than concentration in the Athabasca River upstream of development. Canada's or Alberta's guidelines for the protection of aquatic life were exceeded for seven PPE—cadmium, copper, lead, mercury, nickel, silver, and zinc—in melted snow and/or water collected near or downstream of development (Kelly *et al.*, 2010)

The sampling locations for these two studies are indicated on Figure 16. Parameters sampled are listed in Appendix 1.

1A2.2.2: AENV - snow study 2011

Understanding the relative contribution of regional sources is critical for evaluating emission control strategies, selecting emission control options, and for public understanding. Given uncertainties and knowledge gaps in air contaminants transport and deposition into snow, better understanding of deposition is needed, because of the potential for long-term build-up and transport into the different environmental medias (e.g., water, snow) and because air pollutants may deposit at different rates.

Snow samples were collected in northeastern Alberta over winter (February 2011) to assess PAHs (including alkyl PAHs, following the approach of Akre *et al.* (2004) and total and dissolved metals including ultra trace mercury concentrations in air pollutant fallout across the region. One hundred twenty snow samples were collected across the region by Alberta Environment staff and the collected samples were shipped to analytical labs for sampling analysis. Snow samples consist of known volume cores representing the entire snowpack; location, depth and snow density were recorded. Individual snow core volumes and water equivalents were determined, the snow was melted in the lab and the water analyzed for PAHs, alkylated PAHs, and 24 trace metals that include total metals, dissolved metals, and ultra trace Hg.

The program is expected to conduct data analysis and source apportionment study of snow chemistry data delivered from the analytical lab. The objectives of this study are to : (1) compile the data in a single database and calculate mass load of contaminants in this winter's snow pack, (2) identify the spatial and temporal trends of the fallout elements across the region, (3) determine if there are unique combinations of fallout elements that are characteristic to the major source areas in the region (source area profiles), and (4) use pattern recognition and multivariate statistical techniques and receptor modeling techniques (i.e., US EPA Positive Matrix Factorization (PMF), U.S. EPA 1996, and/or Chemical Mass Balance (CMB) models) to investigate source area apportionment of fallout concentrations measured at downwind locations where plumes from different source areas might mix or through atmospheric transport and deposition (Sunny Cho, Alberta Environment, pers. comm.).

1A2.2.3: Hazewinkel *et al.* atmospheric emission study

The rate of bitumen extraction in northeastern Alberta, Canada, is outpacing the state of ecological understanding of the region, so that the extent of potential disturbances caused by atmospheric deposition remains largely unknown. Atmospheric SO_2 emissions from the Fort McMurray region of Alberta (~300 T.day^{-1}) constitute ~ 5% of the Canadian total. Combined with an estimated NO_x production of ~ 300 T.day^{-1}, these emissions have the potential to acidify surface waters. Diatom assemblages in dated sediment cores from eight acid-sensitive lakes

(see Figure 16) were analyzed to assess the effects of acidifying emissions on boreal lake ecosystems. There is no evidence that these lakes have become acidified. Instead, many of the lakes show characteristic changes towards greater productivity and occasionally greater alkalinity. The absence of evidence for acidification does not imply that emissions from the oil sands are environmentally benign, but rather suggests that the biogeochemistry of these lakes differs fundamentally from well-studied acidified counterparts in northern Europe and eastern North America. Complex interactions involving in-lake alkalinity production, internal nutrient loading, and climate change appear to be driving these lakes towards the new ecological states reported (Hazewinkel *et al.*, 2008).

1A2.2.4: Recent papers from the Western Canada Sulphur & Nitrogen Deposition Workshop

A special issue of the Journal of Limnology (2010) (Aherne and Shaw, eds) includes a number of papers looking at potential geochemical and biological impacts of oil sands stack (and other) emissions on lake systems. Some of these are outside of the area of current interest, but may be useful in future.

Regional emissions of oxidised sulphur and nitrogen compounds increased rapidly over the last 40 years of development in the Athabasca oil sands region, and similar emissions have been linked to lake acidification in other parts of North America and Europe. To determine whether lakes in the region have undergone acidification, 12 lakes within the Regional Municipality of Wood Buffalo and the Caribou Mountains were selected to cover chemical and spatial gradients. Sediment cores were obtained for palaeolimnological analyses including radiometric dating, diatom analysis, isotopic analysis of bulk sediment 13C and 15N, and spheroidal carbonaceous particles (SCPs) (see Figure 16). All lake sediment cores show evidence of industrial contamination based on SCPs, but there is no clear industrial signal in stable isotopes. Most lakes showed changes in diatom assemblages and sediment C:N ratios consistent with nutrient enrichment over various timescales, with potential drivers including climatic change, forest fires, and anthropogenic nitrogen deposition. Only one of the 12 lakes investigated showed strong evidence of acidification with a decline in diatom-inferred pH from 6.3 to 5.6 since 1970. Analysis of mercury (Hg) in the acidified lake showed increasing sediment fluxes over the last 20 years, a possible indication of industrial contamination. The acidified lake is the smallest of those studied with the shortest residence time, suggesting a limited capacity for neutralisation of acid inputs in catchment soils or by in-lake processes (Curtis *et al.*, 2010).

One of the consequences of ongoing development in the Athabasca Oil Sands Region (AOSR) is an increase in emissions of nitrogen (N) and sulphur (S), with an attendant increase in regional atmospheric N and S deposition. Regional land cover across northeastern Alberta is a mixture of Boreal Mixedwood, Boreal Highlands, and Subarctic areas. Peatlands occupy between 22 and 66% of these natural regions, and the land cover of bogs varies between 6.7% in the Mixedwood Region to 46% in the Subarctic Region. Ombrotrophic bog ecosystems may be especially sensitive to atmospheric deposition of N and S. Across 10 ombrotrophic bog sites in the AOSR (see Figure 16) over four years (2005–2008), no evidence was found of elevated deposition. Vertical growth and net primary production of *Sphagnum fuscum*, an indicator of elevated deposition, did not differ consistently across sites. Neither vertical growth nor net primary production of *S. fuscum* was correlated with growing season atmospheric N or S deposition. These data provide a valuable benchmark of background values for monitoring purposes in anticipation of increasing N and S deposition over a broader geographic region within the Athabasca oil sands region (Weider *et al.*, 2010).

1A2.2.5: Environment Canada – snow survey 2011

This project will build upon Kelly *et al.*'s (2009) study, and quantify atmospheric loadings of filtered and unfiltered PACs, multi-elements, total mercury, and methyl mercury to the Athabasca River and its tributaries downwind of the oil sands using snowpack measurements. Snow samples will be collected from 25-30 of the Kelly *et al.* sites located 0-200 km from the upgrading facilities at maximum snowpack depth (late February-early March). Samples will also be obtained from two upwind reference sites: 1) in the town of Fort McMurray, about 35 km from the upgrading facilities; and 2) at the mouth of the Calling River, about 225 km from the upgraders. At each site, snow pits will be dug down to the bottom of level snowpacks and complete snowpack profiles will then be obtained. Ultra-trace sampling techniques appropriate for each contaminant will be used. 10 snow cores will also be collected at each site using an Adirondack corer so that the snow water equivalent (SWE) of snow packs can be obtained by applying the formula: SWE (kg/m^2) = core weight (kg)/(corer radius ($m)^2$). Net spring-time loadings of contaminants to the Athabasca River and its tributaries will be determined using concentrations of contaminants in snow and average SWE (Jane Kirk, Environment Canada, pers. comm.).

1B: MAJOR HISTORICAL FOCUSSED STUDIES AND RESEARCH PROGRAMS, WATER QUALITY AND SEDIMENT

1B1: ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM (AOSERP)

The Alberta Oil Sands Environmental Research Program (AOSERP) was a program established by an agreement between the governments of Alberta and Canada in February 1975 (amended September 1977). AOSERP ran from 1975 to 1980, amassing a large amount of baseline information, at a cost of about 17.4 million. Baseline information gathered through AOSERP on the Athabasca oil sands region was considered complete enough (by 1981) that additional general surveys would not be required (Smith 1981). This assessment is now understood to be premature; both the expansion and pace of development, and many emerging issues, could not have been anticipated at that time.

Atmospheric research for AOSERP culminated in the construction of an air quality model for the region. The land system work established a database for soils and surficial geology, vegetation and wildlife. Water system projects developed baseline information on hydrology, hydrogeology, water quality and aquatic biota. Studies of water chemistry and aquatic biota in the Athabasca River did not reveal significant impacts downstream of Fort McMurray and the two operating oil sands plants at the time, from materials emanating from the industrial operations or municipal sewage and drainage from the town. The "Human System" component research described conditions in the Athabasca oil sands region in historical and contemporary terms. Recommendations for future research were made. The overall assessment of the program concluded that effects of oil sands development were assessed, but not in an integrated fashion. Few interdisciplinary connections were apparent, and this was considered a major deficiency of AOSERP research results (Smith 1981).

Most of the AOSERP reports do not include modern methods of geo-referencing. Figure 17 indicates some studies which have been incorporated into GIS format.

Despite the constraints of converting AOSERP reports and data to a form compatible with modern software, it is evident that valuable information is contained within this program. Continued efforts to mine the AOSERP for information and data are required, since these reports offer a source of historical data that could be useful in establishment of temporal references.

The drainage system of the AOSERP study area [similar to the surface-mineable oilsands area] consists of a number of rivers draining from the west and from the east into the Athabasca River north of Fort McMurray, as well as a few rivers which join the Athabasca near Fort McMurray and drain areas to the south and east. Runoff from within the study area itself contributed less than

10% of the average flow in the Athabasca River at the northern boundary of the study area. Roughly 60% of annual runoff occurred in the 4-month period April through July. Runoff represented on the average only about 20% of the precipitation that fell on the area, the remainder being returned to the atmosphere by evaporation and transpiration. Although snowfall constituted only about 30% of precipitation, its proportional contribution to runoff was generally much greater. Year to year variations in runoff were quite high for many of the rivers draining the study area. For example, annual flow volumes in the MacKay River varied fourfold in only five years of records. In the Athabasca River, annual variations were much less, covering approximately a twofold range in a 20-year period. Few data were available to permit analysis of interactions between surface water and groundwater. Observational well data indicated substantial recharge of groundwater following snowmelt and rainstorms. There were indications that on the east slopes of the Birch Mountains, substantial subsurface flow to the Athabasca River may account in part for the low measurements of runoff in this area (Neill and Evans 1979).

A comprehensive assessment of mixing characteristics of the Athabasca River below Fort McMurray under ice-covered flow conditions was performed by Beltaos (1979a and b). Two tracer tests were conducted in February 1978 to provide the necessary field documentation of the Athabasca River. The results of these tests were analysed using recent theoretical models from the literature. An average value for the transverse mixing coefficient was determined from the results of the first test which was a steady state test. This coefficient compares favourably with that found from a preliminary test in 1974 under similar flow conditions. The results of the second test, which involved central injection of a slug, were compared with a one-dimensional model developed earlier. This model is shown to give fair predictions beyond 20 km from the injection site. To model the results of the slug test within the first 20 km from injection, a numerical algorithm was utilized together with the mixing coefficient found from the first test and shown to give fair predictions. The effects of bars and islands on applications of this algorithm appear to be of localized nature. It is suggested that such effects be ignored unless pertinent hydrometric data are available in considerable detail. Recommendations are made for future research required to completely define the mixing characteristics of the Athabasca River and Delta system (Beltaos 1979).

Prior to 1980, the Muskeg River watershed of northeastern Alberta remained essentially unaffected by oil sands exploitation activities. This predevelopment state, along with its proximity to the AOSERP Field Research Facility, provided opportunity to conduct a large number of baseline studies to define a typical ecosystem within the oil sands area. Hydrological features of the Muskeg River basin were characterized, including physiography, meteorological characteristics, channel characteristics, streamflow, and suspended sediments. The Muskeg River basin was comprised of a large, relatively flat highlands area with steeper headwaters and outflow. The gradient of the mainstem of the Muskeg River ranged from 0.02 at the headwaters to 0.0001 over the highlands. Channels that drain large bogs maintained more winter flow than others. Streamflow characteristics described include: (1) basin-wide flow measurements and their correlation, when possible, with continuous measurements at two sites; (2) spatial distribution of water yields for 1976 and 1977; (3) channel flow volumes for 1976 and 1977; (4) basin-wide high and low flows for 1976 and 1977; and (5) annual flow durations for two sites where continuous measurements were available. Suspended sediment characteristics for the two major sampling sites described include flow loading relationships, concentrations, and loading hydrographs for 1976 and 1977. Basin-wide estimates were made and it was concluded that concentrations are low compared to most data on other Alberta streams. The average suspended sediment yield (3200 tonnes per year) of the Muskeg basin was found to be very low compared to other basins in the oil sands area (Froelich 1979).

Detailed studies of groundwater-surface water systems in the Hartley Creek basin [now commonly referred to as Jackpine Creek, and labelled as such in Environmental Impact Assessments] show the creek to be at baseflow for only a few months in the winter when other contributions to streamflow are negligible. Following spring snowmelt, drainage of muskeg is the major contributor to streamflow along with groundwater inflow. Similar patterns of streamflow

generation were observed for Firebag, Steepbank, and Muskeg rivers as well as Thickwood Creek. Quantitative hydrograph separations for these basins show that the main differences result from variable amounts of inflow from muskeg during winter. Muskeg River like Hartley Creek [Jackpine Creek] is close to baseflow in winter. However, in Firebag River and Thickwood Creek, drainage from muskeg may comprise as much as 40 to 50% of the streamflow in winter. A three-year study of the Muskeg River basin with particular emphasis on the Hartley [Jackpine] Creek sub-basin, was undertaken. The Steepbank, Firebag, and Thickwood basins were also analyzed, to test of the usefulness and generality of the approach. Streamflow in all basins will be influenced by the disturbance of muskeg. For the particular case where muskeg is removed and replaced by mineral soils, stream discharge will tend to decrease during summer and to increase during spring runoff and stormflow periods. In cases where the local disturbance of muskeg is considerable, marked variation in streamwater chemistry can be anticipated (Schwartz 1980).

A number of AOSERP projects involving water quality sample collection and analysis were instituted. These projects followed AOSERP's general objectives (Smith 1981) which were, generally, the definition of baseline states and detection of changes that might be caused by the development of the Athabasca oil sands. Under the regional surface water quality monitoring program, the standardization of sampling sites, procedures, and analysis received significant attention. Documentation of the locations of water quality sampling sites as well as the sampling, analytical, and quality control methods used, the volume and availability of assembled data, and a comprehensive appraisal of the quality of the database, can be found in Akena (1980).

Akena and Christian (1981) provided an assemblage of non-AOSERP surface water quality data dating back to the 1950s (see Figure 17). Most of the data were abstracted from reports of federal and Alberta government departments, Alberta Research Council, universities, oil sands industry, and private consulting firms. Unfortunately, the studies used a wide variety of sample collection, storage, and analysis procedures; and, in a large number of cases, the databases did not contain clear descriptions of the exact locations of sampling sites, consistent sites and parameters monitored, documentations of the sampling procedures, sample preservatives, analytical methods, detection limits, or precision, or indications of the quantity, quality, or accuracy of the database. It was hoped that the compilation of surface water quality data could be used to supplement the AOSERP surface water quality database, especially in areas where, or on occasions when, AOSERP data were not collected (Akena and Christian 1981).

Exploitation of the bituminous sands may elevate heavy metal levels in the sediments of drainage systems of the AOSERP area via waterborne or airborne emissions. One hundred and six dredged sediments and twenty-four sediment cores were collected from the Athabasca River system from just above Fort McMurray to the confluence of Rivière des Rochers with the Slave River. A preliminary sample suite representing all of the drainage units and textural variations was selected for detailed analyses by several total and partial extraction techniques. This included 21 samples. The objective was to document the natural heavy metal geochemistry of the sediment and to assess cultural influences if any on concentrations. Preliminary analyses indicated that absolute concentrations were low when compared to data for polluted sediments or even for sediments from different natural geological terrains elsewhere. Concentration variations appeared to be functions of natural sedimentological, mineralogical and geochemical controls. The highest heavy metal concentrations occurred in the finest grained sediments from Lake Athabasca. Vanadium, the heavy metal most commonly associated with the oil sands, appeared to be present in the drainage sediments in a stable organic compound. It appeared to be unaffected by chemical or bacterial degradation in the bottom sediment (Allan and Jackson 1977).

Dredged sediments and sediment cores were collected (see Figure 17) from sites along the Athabasca River system from between Fort McMurray and the confluence of Rivière des Rochers with the Slave River. A selected sample suite representing all of the drainage units and textural variations was analysed by several total and partial element extraction techniques. The metal concentrations detected were not considered unusual. The results indicated that total

concentrations were low when compared to data for natural and for polluted sediments elsewhere (at that time). Concentration variations were strongly affected by sedimentological parameters including sediment texture, Fe/Mn mineral coatings and organic and carbonate contents. There was a general progression to higher concentrations of heavy metals downstream from the Athabasca River to its delta to Lake Athabasca. The highest heavy metal concentrations were in the fine textured sediments from Lake Athabasca. Vanadium and nickel were strongly correlated with each other and with organic carbon content (Allan and Jackson 1978).

The wastewaters from the existing oilsands extraction plant were characterized and quantified by Strosher and Peake (1976). In November and December of 1975 ten samples were taken from the tailings pond dyke filter drainage system, the upgrading plant final effluent, and the intake pond water. A number of specific aromatic hydrocarbons and organic sulphur compounds were identified, and heavy metals including vanadium were determined. A large percentage of the tailings pond dyke filter drainage samples contained organic carbon which was extractable by organic solvents. Upgrading plant effluent contained only a small fraction of organic extractable carbon compounds. Daily averages of organic carbon were calculated as releases to the river from the tailings pond dyke filter system and the upgrader effluent. It was recommended that further studies be conducted on those and other wastewaters on a year-round basis to determine seasonal variations in amounts of organic constituents, the identities of individual compounds, the toxicity of compound groups, and the physical state of the organic compounds. Studies to characterize the organic constituents in Athabasca River water were also recommended (Strosher and Peake 1976).

Investigations were carried out on the Athabasca River upstream of Fort McMurray to determine the baseline quantities of organic constituents and their contribution to the organic water quality of the river system as it continues through the Athabasca Oil Sands strip mining area. Water soluble constituents, tannins and lignins, asphaltenes, and polar constituents were the major organic components of the river system as determined from the 16 different investigations carried out. Water samples contained an average 9 mg/l of organic carbon, the majority of which was determined as dissolved organic carbon. Water soluble organics, which included the humic acids, averaged 6.9 mg/l and were the largest single organic component of the river water. Also contained in this water soluble fraction were the naturally occurring tannin and lignins at 0.24 g/l. The extractable carbon fraction contained 20% asphaltenes, 33% polar constituents, and 10% hydrocarbons. Tannins and lignins were the largest group of compounds detected in the sediments but comprised only 3% of their unextractable carbon fraction. Extractable organic carbon fractions contained 39% asphaltenes, 17% polar compounds, and 16% hydrocarbons. It was concluded that organic constituents which occur in this segment of the river were mainly water soluble, naturally occurring compounds that persist consistently throughout this upstream study area. Measurements to assess the assimilative capacity of the river system indicated that minimal uptake of the majority of organic matter occurred in this river section, thus providing a constant natural input to the river system at Fort McMurray (Strosher and Peake 1979).

Analyses were undertaken for up to 12 metals and 4 pesticides with polychlorinated biphenyls (PCBs), of aquatic environmental samples from 15 study sites along or near the Athabasca River from Fort McMurray north to the confluence of the Peace and Slave Rivers, including fish, 15 water (filtered and unfiltered), 14 sediments and a few phytoplankton and invertebrate samples. All samples were frozen until analysis by AAS and GLC. In water, As, Cr and Cd were mostly <1, <6 and <0.1 µg/L respectively, below previously reported values for the Athabasca River at Fort McMurray. Cu (excepting 3 stations with 12 to 97 µg/L) averaged 2 µg/L. Fe, mostly particulate, and averaging 2500 µg/L was higher than reported for many upstream waters, but in line with previous analyses for the area. Mn was also relatively high at 43 µg/L, mean; it was particulate and also related to iron content. Ni, (except for 2 stations) averaged 3.4 µg/L, and V (one station excepted) was 3.1 µg/L, mean. Vanadium was below the mean of 6 µg/L found for many samples of drinking water in the US. Zn in 12 stations averaged 23 µg/L, in line with earlier analyses from the area. Some high values may have been due to contamination. At the time samples were analyzed, phenol was below the detection limit but could have decomposed on storage. Mercury

was not analyzed in the water samples due to sample preservation. Sediments were quite high in Fe content (5750 to 22400 µg/g) and in Mn (110 to over 300 µg/g). There were positive correlations between iron content and (in descending order) V, Zn, Mn, Se, As, Cu. Cr, with a weaker one for Cd. No metal concentrations seemed in any way unusual. Mercury contents in these sediment samples were low. Ni and V content were positively correlated. The reported values reflect the baseline levels of trace metals in the sediments in this area (Lutz and Hendzel 1977).

Seasonal and geographic variations in significant water quality parameters in the Muskeg River basin of northeastern Alberta, prior to oilsands development in the watershed, were described by Akena (1979). Specific conductance and the concentrations of major ions (Ca+2, Mg+2, HCo3 -, and, to some extent, Na+ and Cl-) generally exhibited relatively stable seasonal levels, except for occasional fluctuations caused by storm events or deep groundwater flows. The relationship between physiographic features and watershed water quality indicated that water and chemical storage/movement in muskeg areas play a major role in maintaining or influencing observed patterns, levels, and loadings of Ca and Mg, as well as Na:Cl ratios. Good regression relationships, between index variables (specific conductance and discharge) and the concentrations of major ions and related parameters, were found. It was possible to calculate annual loads discharged through the major sampling sites. Fluctuations in the dissolved oxygen regime were influenced by sub-basin dependent physical factors (turbulence, turbidity, and temperature) as well as changes in algal and microbial populations. "Free" CO_2 and pH variations reflected fluctuations in biotic respiration, biochemical decomposition, and photosynthetic processes. Changes in microbial communities were also analysed in relation to macronutrient concentrations and the assimilative capacity of the streams. Orthophosphate phosphorus and nitrite+nitrate concentrations were generally low, especially during the ice-free period. This may be due to low watershed release and/or microbial uptake. The dissolved organic carbon (DOC) and ammonia-nitrogen concentrations peaked at approximately the same time (dissolved organic nitrogen, DON, peaked a month earlier); the coincidence appeared to inhibit nitrification. DOC to DON and ammonia to nitrate/nitrite ratios, along with variations in ammonia concentrations, indicate that bacterial communities in streams of the Muskeg River basin were effective in converting organic substances to nutrients. Levels of K, B, Co, Ni, Hg, Pb, Cu, and Zn were found to be influenced by biotic factors. The observed levels of certain metals were lower than Alberta Surface Water Quality objectives, while for As, Hg, Ni, Zn, Fe, and Mn, the objective levels were exceeded. The higher baseflow concentrations of extractable Cr, Pb, Zn, V, Ni, Fe, Al, Mn, Cu, and Co were associated with the particulate rather than the dissolved phase (Akena 1979).

The assimilative capacity of the Athabasca River has been defined as the ability of the river to respond to effluent loading and still maintain its productivity and diversity. In order to estimate the assimilative capacity, it is necessary to understand the processes of degradation, the amounts and types of effluent which reach the river, and seasonal effects. To do this, a working conceptual model of the river must be established and built up to the point where predictions of the effects of effluent loading can be made. Consideration of organic input sources, concentration in the river, mixing characteristics, processes of degradation, and toxicity would need to be included. To assess whether a framework of understanding which might be developed into a working predictive model would be possible, existing data were synthesized. The data used in this report were either provided by studies in the Alberta Oil Sands Environmental Research Program or taken from other reports. The available data at the time were judged insufficient for modelling of assimilative capacity. Gap analysis, and a research plan to address these information gaps, were provided, with the goal of eventually developing sufficient information to create a model with the ability to predict the effects of various organic inputs to the river. Programs of water and sediment chemistry and biomonitoring were proposed (Wallis *et al.*, 1980).

A fisheries and water quality survey was conducted in September 1979 on 10 small lakes (67.4 to 338.9 ha) in the vicinity of Richardson Tower, approximately 140 km north of Fort McMurray, Alberta. The major objectives were: to determine morphometric and water quality characteristics in relation to habitat requirements for indigenous and possible introduced species of fish; to

assess potential fish yield; and to determine the susceptibility of the lakes to acidification. Water quality was fairly uniform with moderate concentrations of dissolved solids (total filterable residue slightly above 100 mg/L), calcium and bicarbonate at the major ions, and low phosphorus levels. Waters were clear, largely unstained, and generally well oxygenated. Mean total alkalinity of the study lakes was 77 mg/L (1.53 meq/L). Although terrestrial buffering responses were uncertain, it appeared that lakes were not highly susceptible to acidification (i.e., at precipitation acidities foreseeable for the study area) (Ash and Noton 1980a and b).

Twenty lakes in the AOSERP study area, surrounding the area of current oil sands processing operations, were surveyed in October 1976 to determine their susceptibility to pH change resulting from atmospheric acid additions. Major element chemistry and nutrient concentrations were measured in the water and suspended particulates. Models using the survey information were presented for prediction of the change in pH of these lakes under various acid loading rates. Most of the lakes in the region had high alkalinities and high resistance to pH change. The only lakes which might be susceptible to serious pH alteration under high acid load were those in the Birch Mountain area. However, the simple steady state model developed in this report suggested that the more poorly buffered lakes sampled in the Birch Mountain region would only be seriously affected if the pH of rain averaged below 4.0. The report concluded that that a drop in rain pH in this area to below 4.0 seemed unlikely, since Sudbury, Ontario, with a much greater output of sulphuric acid, had rains averaging 4.0 to 4.5 in pH (Hesslein 1979).

1B2: TERRESTRIAL, RIPARIAN, ORGANISMS, LAKES, STREAMS STUDY (TROLS)

A project that generated some potential reference stream data in what is now an *in situ* oil sands development area was the "Terrestrial, Riparian, Organisms, Lakes, Streams" study (TROLS). This study was largely within the Christina River watershed.

The TROLS study objective was twofold: (1) to assess the impacts of timber harvest and (2) to assess the effect of forest fires on streams in the mixed-wood boreal forest of northern Alberta. To assess the effects of timber harvest, 4 locations on each of 5 streams south-east of Fort McMurray were sampled both before and after timber harvesting operations. Samples were collected in 1994 prior to winter 1994/95 timber harvest and continued until 1997. To assess the effects of the forest fire on stream ecosystems, 11 streams were sampled within and six reference streams around the perimeter of a burned area south-west of Fort McMurray. Streams were sampled immediately after the June 1995 forest fire (near Mariana Lake) and continued for approx. 3 years. Sampling was conducted for nutrient, cation, anion and carbon concentrations in the stream water; discharge, forest cover, benthic algal biomass and benthic invertebrate composition were also determined (Patricia Chambers, Environment Canada, pers. comm.).

TROLS work offers the potential for pre-development water quality reference information in an area now under development by *in situ* oil sands projects. This will be relevant to future Phase work of the present water quality monitoring plan, when geographic scope is enlarged.

1B3: NORTHERN RIVER BASINS STUDY (NRBS)

The Northern River Basins Study (NRBS) was established in 1991, representing a joint agreement between the governments of Canada, Alberta and the Northwest Territories. A primary objective of the Study was to advance understanding of how developments within the Peace, Athabasca and Slave River basins have had cumulative impacts on the mainstem and main tributary aquatic ecosystems. The Study was also to provide the necessary knowledge-base and tools required to assess the potential consequences of future developments. To achieve this, the NRBS and its eight research component areas focussed on gathering and interpreting comprehensive information on water quality, contaminant distribution, fate and effects, benthos, fish and fish habitat, riparian vegetation/wildlife, hydrology/hydraulics, drinking water quality,

nutrients, dissolved oxygen, traditional knowledge and use of aquatic resources within this region (Wrona et al., 1996).

The Bennett Dam at Hudson Hope, British Columbia was completed in 1968 and by early 1970 was thought to affect the hydrology and ecology of the Peace-Athabasca Delta. By 1990, forestry-related land clearing was expanding to meet the needs of six active pulp-mills and there were plans for more mills. Agriculture in the Athabasca basin was not perceived as a major land use; however, in the settled areas along the Peace River and its tributaries, agriculture was becoming a dominant feature. The Northern River Basins Study grew out of a general public perception that the ecosystem was increasingly threatened by anthropogenic activity. This perception crystallized in the late 1980s at the time of the proposal to construct the Alberta-Pacific pulp-mill (AlPac) at the town of Athabasca. A primary recommendation of the AlPac Environmental Impact Assessment Hearings in 1990 dealt with the importance of assessing cumulative environmental impacts and underscored the need to obtain an improved understanding of the ecology of the basins placed within the context of societal concerns and objectives. Limited information was available on a variety of key ecosystem components and processes including: fish ecology; the response of aquatic biota to effluent exposure; the presence, distribution, fate and effects of contaminants; drinking water quality; and the consequences of flow regulation (Wrona *et al.*, 1996).

The NRBS developed sixteen guiding questions to provide scope and focus for the research. These questions and the research program were structured to address information deficiencies, and to build upon the existing knowledge base for these basins. Implicit in the guiding questions was the need to adopt an ecosystem-approach to the study of environmental stressors and to implement a cumulative effects philosophy in the design and interpretation of the research. The objectives of the research program were to identify and quantify the multiple and diverse stressors acting on the Athabasca, Peace and Slave river basins and to assess the ecological consequences of exposure to those stressors. It was understood that the effects of multiple stressors (e.g., nutrient additions, contaminants, changes in river flow) operating simultaneously on the ecosystem may be difficult to assess and predict. This was further complicated by the synergistic and antagonistic effects of multiple stressors (e.g., nutrient/contaminant interactions) and by the effects manifested at a variety of spatial (e.g., reach-specific versus basin-wide), temporal (e.g., within- versus among-years) and organizational (e.g., the individual, population community, ecosystem) scales (Wrona *et al.*, 1996).

A review and synthesis of the existing reports and databases provided by the Northern River Basins Study (NRBS) on instream nutrient concentrations and nutrient loading was developed. Longitudinal trends in the water chemistry of the Athabasca River were identified in the 1980's. The increase in nutrients down the river system was due to point sources and natural tributary inflows, which often have higher concentrations of phosphorus and nitrogen than the mainstem. When all tributary and point-source anthropogenic loads to the Athabasca River were considered, the total phosphorus load measured near the delta during the winter of 1991 was only 36% of the sum of the inputs, indicating a substantial removal of phosphorus from the water column. In contrast to phosphorus, the concentration of total nitrogen increased at downstream locations. Concentrations of phosphorus and nitrogen increased during the rising hydrograph due mainly to increases in the particulate fraction. There were five continuously discharging municipal sewage treatment plants, four operating pulp mills and one mill under construction on the Athabasca River and its tributaries. Treated sewage from Fort McMurray was the largest nutrient load from municipal sources. Nearly half of the average annual flow to the Athabasca River comes from the tributaries which contribute a large nutrient load to the mainstem of the river. Other point sources of nutrients such as the Suncor effluent and H.B. Milnor power station effluent were relatively minor (SENTAR Consultants Ltd 1994).

Another study undertaken as part of the NRBS aimed to assess the sources of nitrogen and phosphorus to the Athabasca and Wapiti- Smoky rivers and evaluate the need to consider groundwater contributions when undertaking simulation modelling of chemical parameters of the Athabasca River during winter. To address the first objective, longitudinal trends in N and P were

examined for each river system in relation to point-source inputs and the contributions of anthropogenic point sources and agricultural activity to the rivers' nutrient loads were quantified. The importance of groundwater during winter was assessed by examining hydrologic mass balances and changes in dominant ion proportions. Examination of flow budgets and ionic composition of the mainstem surface waters of the Athabasca River for the 1989 to 1993 winters indicated that, for most winters, it is unlikely that there are large localized inputs of groundwater during winter. Comparison of the sum of headwater and tributary flows with the measured flow at Fort McMurray showed that the percentage of downstream discharge accounted for by known sources was, on average, 86% (66 to 106% range). While this unaccounted discharge may be due to groundwater inputs, some of this discrepancy is undoubtedly due to difficulties in measuring discharge under-ice cover. Increased periphyton growth was observed during autumn downstream of Jasper, Hinton, Whitecourt, Athabasca, Fort McMurray and Grande Prairie (Chambers and Dale 1997).

The Northern River Basins Study commissioned Environment Canada to undertake bottom sediment surveys of the Athabasca and Peace River basins in October 1994 and May 1995. The surveys were undertaken to partially address the distribution of and temporal changes in contaminants in the Peace, Athabasca, and Slave River basins. The 1994-95 bottom sediment surveys had four objectives: to determine the spatial distribution of contaminants in bottom sediments in the Athabasca and Peace River systems during 1994-95; to determine within-site variability in bottom sediment contamination at a number of locations; to test the assumption that the sand fraction is not an important repository of contaminants, and; to provide a 1994-95 dataset for comparison with earlier bottom sediment collections in 1988-89 and 1992. Sediment/contaminant parameters included particle size and carbon, resin acids, PAHs, polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs/PCDFs), chlorinated phenolics (CPs), PCBs, extractable organic halides (EOX), toxaphene, and total mercury. The highest levels of sediment resin acids were found on the Athabasca River near Emerson Lakes, and on the Peace River upstream of the mouth of the Smoky River. The highest total PAH concentrations were found in the lower basin of the Athabasca River, and in the upstream sites on the Peace River. The highest concentrations of chlorinated phenolics were found downstream of bleached kraft mills in the upper Athabasca River. Dioxins and furans were present in low concentrations in bottom sediments of both river basins, and the results do not indicate widespread contamination from pulp mill effluents. Spatial trends in PCBs were not apparent in either basin. No detections were reported for EOX, toxaphene, or total mercury. Results of the within-site variability analyses varied with the compounds tested, demonstrating the need to sample intensively within a reach to produce a representative composite sample. Mean concentrations of some compounds were higher in the sand fraction than the clay-silt fraction of depositional sediment samples (Crosley 1996).

After the sediment and sediment-associated contaminant sampling field programs were completed, a retrospective review of river processes affecting sediment-associated contaminant dynamics was provided. In terms of dynamic sampling, this report examined sediment fluxes through the use of published material from the conventional Water Survey of Canada suspended sediment monitoring program. In addition, the reach-scale mass balance of suspended sediment undertaken by NWRI, and special sediment-associated contaminant flux measurements undertaken for NRBS with centrifuge sampling were examined. Many of the contaminants of concern in the Northern River Basins study area had a strong affinity to sediment. As a result, the distribution, pathways and fates of many contaminants were closely related to the dynamics of the riverine sediments. The report concluded that while NRBS results have yielded some interesting observations, it would have been most useful for the monitoring and assessment of sediment work to be established prior to any field work being undertaken (Carson and Hudson 1997).

Environmental levels of mercury in water, sediment, invertebrates, and fish from the Athabasca, Peace, and Slave River basins were reviewed. Data were obtained from existing provincial and federal databases, the Northern Rivers Basins Study, and from government and private sector

reports and publications. Mercury had been measured in several hundred water samples from the basins. Mercury was detected in only a few of these samples. However, appropriate field and laboratory protocols to sample mercury in water were not used in the past; thus most detections of this element in water may not be reliable. It is noteworthy however, that because of high detection limits (0.05 to 0.1 μg/kg) mercury was not detected in most municipal effluents, and only occasionally in industrial effluents. Mercury is ubiquitous to all soils and sediments of the earth, and it is not surprising that it was found in sediment samples from the basins at levels that range from 27 to 123 μg/kg (dry weight). Levels of mercury found in sediments were well below the current draft interim sediment guideline for mercury that was developed to protect aquatic life, 170 μg/kg mercury (dry weight). There was no obvious increase in mercury in sediments downstream of industrial effluents compared with sediments at upstream sites. Sediment cores from Lake Athabasca indicate that mercury levels have not increased over at the past 50 years or more, and they also suggest that the Athabasca River basin is the principal source of mercury to Lake Athabasca (Donald *et al.*, 1996).

A field investigation covering the portion of the Athabasca River between Athabasca and Bitumount was performed to define the hydraulic and mixing characteristics of the river reach. Twelve sample sites were selected within the 464 km long study area. The river was divided into three reaches in which separate tracer dye experiments were performed to determine travel times and dispersion coefficients. The mixing process was split into a number of zones in which different processes were dominant. Vertical mixing was found to be virtually instantaneous with vertical mixing lengths between 15 m and 27 m. Transverse mixing was found to be complete between 52 km and 82 km downstream of the injection points. Linear dispersion parameters were lower than values previously measured on the Athabasca River under an ice cover and also lower than values on other ice covered rivers (Van Der Vinne 1993).

Results of contaminant analyses were presented for bottom sediments collected from the Peace and Athabasca River basins from 1988-90 by Alberta Environmental Protection and in 1992 by the Northern River Basins Study. While most of the sites were associated with upstream pulp mills, sampling was also performed on the Athabasca at Fort McMurray, above the Horse and Firebag Rivers, and in the Athabasca Delta. Contaminant groups represented were the polychlorinated dibenzo-p- dioxins and dibenzofurans, resin acids, chlorophenolic compounds and polycyclic aromatic hydrocarbons. Contaminant concentrations were correlated with percent organic carbon of the fine fraction (the fraction on which contaminant analyses were performed). There was no significant correlation. Organic carbon content of the sediments was a poor predictor of contaminant concentration. Correlations between concentrations of bleached kraft mill-related contaminants were also investigated (Brownlee *et al.*, 1997).

NRBS studies are thus another source of potentially useful data for reference and comparative purposes. In particular, NRBS data from near pulp mills may be compatible with Environmental Effects Monitoring (EEM) data, and could provide higher n for statistical power analysis. NRBS water quality data should be retrievable from the Alberta Environment water quality database, as well as the NRBS database itself.

1B4: ATHABASCA RIVER PROJECT

The Athabasca River Project included research coordinated by the National Water Research Institute to study the impact of industrial activities on the Athabasca River, particularly the oil sands operation near Fort McMurray, and the contribution of these operations relative to natural sources and upstream industrial activities. As well, modelling of the hydrological and chemical characteristics of the river was undertaken. The emphasis was on polycyclic aromatic hydrocarbons (PAHs) and related compounds. Water, suspended sediment and bed sediment from the Lower Athabasca River, its' tributaries, and the lower Peace and upper Slave Rivers were analyzed for organic contaminants and tested for ecotoxiciological response. Fish were also collected in the vicinity of oil sands plants, and analyzed for PAHs and metabolites, and for mixed

function oxidase activity in liver tissue (Brownlee 1990, Bourbonniere 1992). Sampling on the lower Athabasca included bulk chemical and physical parameters, heavy metals in water, sediment and fish samples, volatile organics under ice in the mainstem, suspended sediment/bacteria relationships, hydrologic modelling and biodegradation of polyaromatics. The original project proposal was prepared in March 1989, focussing on the fate, pathways and effects of PAHs, nitrogen and sulphur containing PAHs and methyl homologs, studying the principal transport vectors of suspended sediment and water, and measuring effects on resident fish communities and ecotoxicological assays. Collaborating agencies included Alberta Environment, the Department of Fisheries and Oceans, the Inland Waters Directorate, Water Quality Branch [now Water Quality Monitoring and Surveillance], and Wood Buffalo National Park (Bourbonniere 1992). This project had some overlap with NRBS and other PERD studies, due to commonality of personnel and topics.

Another Athabasca River Project study looked at mixing characteristics of the Athabasca River using conservative ions (Booty 1993). In many rivers complete sectional mixing is not achieved for long distances from the initial release point of a pollutant. This is the case for the Athabasca River downstream of Ft. McMurray. A two dimensional toxic chemical model was under development at the National Water Research Institute, to examine the transport and fate of these contaminants. Because of the complex nature of the mixing processes, field tests were required to supply mixing data for the model for a wide range of flow conditions. In order to supplement the few tracer dye studies which have been performed, the mixing of natural water quality parameters at the confluence of the Athabasca and Clearwater Rivers was used to simulate a steady-state tracer test. The diffusion and dispersion values obtained from this study were compared with earlier dye tracer studies as well as a similar natural water quality tributary mixing study performed 18 years earlier (Booty 1993).

1B5: NORTHERN RIVERS ECOSYSTEM INITIATIVE (NREI)

To address the recommendations of the NRBS, as well as the public demand for follow-up studies, the Northern River Ecosystem Initiative (NREI) was set up in 1998. The five-year study focussed on priorities such as pollution prevention, endocrine disruption in fish, hydrology, contaminants, nutrients, safe drinking water and enhanced environmental monitoring. Its mission was to provide the scientific underpinning to the governments' responses to the recommendations of the NRBS. (Northern Rivers Ecosystem Initiative [Canada], 2004).

Concerns over potential changes to the hydrology of the Athabasca and Peace Rivers and downstream Peace-Athabasca Delta as a result of human development and climate variability/change led to a number of research initiatives involving Environment Canada over the last 40 years: Peace-Athabasca Delta Project Group (PAD-PG 1973), the Peace-Athabasca Delta Implementation Committee (PAD-IC 1987), Peace-Athabasca Delta Technical Studies (PAD-TS 1996), the Northern Rivers Basin Study (NRBS 1996) and the Northern Rivers Ecosystem Initiative (NREI 2004). Collectively, these programs examined climate variability/change, land-use change and flow regulation effects on river, delta, and lake hydrology and aquatic ecology upstream of Great Slave Lake. In particular, NREI included key hydrological studies with a focus on the Athabasca River Watershed and Delta: historical analysis of spatio-temporal streamflow generation to seasonal high flows to the Delta (Peters and Prowse, 2006); and hydrological modelling assessment of anticipated effects of future climate change (2040-2069 vs. 1961-90) on streamflow generation to the mouth of the river (Toth *et al.*, 2006). These and other relevant hydro-ecological studies are included in a Hydrological Processes Special NREI – Hydrology Issue (Wrona and Gummer 2006).

Most of the NREI studies fall outside of the topic and geographic scope of Phase 1 Component 2, as this document focuses on the physical and chemical aspects of water quality. Phase 2 Geographic Expansion component 2 examines biological aspects of water quality as well as physical (Lindeman *et al.*, 2011).

1B6: WATER SURVEY OF CANADA HISTORIC SUSPENDED SEDIMENT LOAD INFORMATION

As discussed in section A1.2, river velocity measurements are performed to estimate streamflow. In some selected gauges, as streamflow varied, hydrologists also took water samples that were later analysed to determine the quantity of suspended sediments carried by the stream for different flow conditions. Both streamflow and sediment concentration continually change. An important driver is the amount of material that is available for mobilization from stream bed or banks. Due to infrequent observations, a high degree of subjectivity was involved in the daily sediment loading determinations. Uncertainty estimates varied with flow conditions, but values of 100% or more can be demonstrated in this historic data.

The sediment monitoring program was cut after program review in 1993. WSC no longer has the capacity to do this work.

Table 2, below, provides more detail on sediment data that has been available. These data can be downloaded from the WSC web site. The following table highlights the years of sediment data that can be made available, and distinguishes between discrete measurements (these measurements were made at various intervals) and continuous measures.

Table 2: Water Survey of Canada stations for which historic sediment data are available.

Station	Station Name	Hydat Status	Latitude Degrees	Longitude Degrees	Drainage Area km	Years	From	To	Reg.	Oper Sched	Suspend	Load
07CA005	PINE CREEK NEAR GRASSLAND	Active	54.8204	-112.778	1456.4	44	1974	1983	FALSE	Miscellaneous	Discrete	Discrete
07CD001	CLEARWATER RIVER AT DRAPER	Active	56.6853	-111.255	30791.6	56	1967	1987	FALSE	Miscellaneous	Continuous	Continuous
07CD004	HANGINSTONE RIVER AT FORT MCMURRAY	Active	56.709	-111.356	962	45	1978	1980	FALSE	Seasonal	Discrete	Discrete
07DA001	ATHABASCA RIVER BELOW MCMURRAY	Active	56.7803	-111.402	132585	5	1967	1972	FALSE	Continuous	Continuous	Continuous
07DA005	BEAVER RIVER NEAR FORT MACKAY	Discontinued	57.1	-111.633	454	10	1975	1975	TRUE	Miscellaneous	Discrete	Discrete
07DA006	STEEPBANK RIVER NEAR FORT MCMURRAY	Active	56.9995	-111.407	1319.85	38	1975	1983	FALSE	Seasonal	Discrete	Discrete
07DA007	POPLAR CREEK NEAR FORT MCMURRAY	Discontinued	56.9139	-111.46	151	15	1974	1983	TRUE	Seasonal	Mixed	Mixed
07DA008	MUSKEG RIVER NEAR FORT MACKAY	Active	57.1912	-111.57	1457	36	1976	1983	FALSE	Seasonal	Discrete	Discrete
07DA016	JOSLYN CREEK NEAR FORT MACKAY	Discontinued	57.2742	-111.742	257	19	1976	1983	FALSE	Seasonal	Discrete	Discrete
07DA018	BEAVER RIVER ABOVE SYNCRUDE	Active	56.9453	-111.566	164.8	35	1976	1980	FALSE	Seasonal	Discrete	Discrete
07DB001	MACKAY RIVER NEAR FORT MACKAY	Active	57.2104	-111.695	5569.3	38	1975	1983	FALSE	Seasonal	Discrete	Discrete
07DC001	FIREBAG RIVER NEAR THE MOUTH	Active	57.6511	-111.203	5987.6	39	1976	1983	FALSE	Seasonal	Discrete	Discrete
07DD001	ATHABASCA RIVER AT EMBARRAS AIRPORT	Discontinued	58.205	-111.39	155000	14	1971	1984	FALSE	Seasonal	Mixed	Mixed
07DD003	EMBARRAS RIVER BELOW DIVERGENCE	Active	58.4222	-111.551	0	21	1971	2009	FALSE	Seasonal	Discrete	n/a

1B7: OTHER STUDIES

Baseline studies of aquatic environments in the Athabasca River were carried out at the request of Syncrude Canada Limited and were focused in the vicinity of Syncrude's Lease Number 17, which borders the west bank of the Athabasca River north of the town of Fort. McMurray, Alberta. As one component of the study, Aquatic Environments Ltd. (AEL) carried out detailed analyses of

various aspects of water quality in the Athabasca River. The overall objective of these studies was to build a data set which contained information relevant to understanding geographic and seasonal variation in various parameters. It was envisioned that the acquired data would serve as a basis for monitoring any changes which may occur as the Syncrude development proceeds. Parameters measured included discharge (provided by the Water Survey of Canada), water temperature, specific conductance, pH, turbidity, suspended sediment, dissolved oxygen, major ions and macronutrients. Fifteen water quality stations were sampled fourteen times over the course of the study and nineteen water quality sites, some of them permanent stations, were sampled once in February of 1975 as part of a comparison between the west and east banks of the Athabasca River. Not all parameters were sampled on all dates. Winter samples showed increasing trends of ions, and it was concluded that saline groundwater discharge in the winter was a source. This effect was less pronounced during the ice-free season when the influence of groundwater was masked by surface runoff of the calcium carbonate type. A distinct seasonal pattern of TDP was also observed, with peaks during the high water period. A mid-winter low of reactive silica was also observed. The data used in the modeling exercise study were directly provided to the modellers from the Alberta Environment EQMB database (Aquatic Environments Ltd. 1977).

Baseline studies of aquatic environments in the MacKay River were carried out at the request of Syncrude Canada Limited and were designed to provide an adequate bases against which further changes in the aquatic environment of the MacKay River could be compared. One of the objectives of the study was to describe the seasonal variability of various physical and chemical characteristics of the MacKay River which flows through Syncrude property and into the Athabasca River. Samples were collected on eight occasions from March 1977 to January 1978. Parameters analyzed include NO_3, total nitrogen, total phosphates, orthoPO_4, reactive Si, turbidity, suspended sediments, total solids, total dissolved solids, volatile solids, true colour, pH, COD, TOC, alkalinity, hardness, Cl, SO_4, macronutrients, some metals, temperature and DO. Concentrations of dissolved substances were found to be greatest in the winter and lowest in summer, presumed to be due to a groundwater influence. Suspended sediment loads were highest in June and lowest in late summer and fall, but increased again in winter (Aquatic Environments Ltd. 1978).

Similar historical and recent reports from other industry studies exist, but can be difficult to access.

In response to the rapid expansion in the pulp mill industry and the concern about winter water quality in the Athabasca River, five water quality surveys were carried out in January to March of 1988 and 1989. The data were compared to previous data, effluent impacts were assessed, and compliance with the Alberta Surface Water Quality Objectives (ASWQO) and the Canadian Water Quality Guidelines (CWQG) evaluated. Effluents to the Athabasca River at the time were the Hinton pulp mill and municipal effluent (HCE), the Millar Western Pulp Ltd. (MWPU effluent) (1989 only), treated municipal sewage from Whitecourt, Athabasca and Fort McMurray, and the Suncor Oil Sands process effluent. The pulp mill effluents had adverse effects on concentrations of dissolved oxygen, phenolic compounds, trace organic compounds, colour, odour, phosphorus, and manganese in the Athabasca River. This resulted in non-compliance with the ASWQO and/or the CWQG for oxygen, phenols, colour, odour and phosphorus. Heat in the effluent created an ice-free reach downstream of each mill. In addition, the pulp mill effluents increased river concentrations of sodium, chloride, sulphate, sulphide, suspended solids, tannin and lignin, organic carbon, nitrogen, and bacteria, and they discharged a high load of zinc. These findings are consistent with assessments carried out previously with regard to the bleached kraft pulp mill on the Wapiti-Smoky River system. The municipal sewage effluents caused small to moderate increases in nitrogen, phosphorus, and bacteria in the Athabasca River. No effect of the Suncor Oil Sands effluent on river water quality was discernible. Concentrations of calcium, magnesium, bicarbonate, alkalinity, hardness, pH, fluoride, and most metals were not adversely affected by effluent discharges (Noton and Shaw 1989).

Expansion in the pulp and paper industry on the Athabasca system has raised concerns about water quality, since the industry generates significant volumes of wastewater. Water quality monitoring and surveys on the Athabasca River were increased substantially after 1987, including winter "synoptic" surveys, new monitoring sites, installation of recording oxygen meters in winter and applied studies to assess impacts or obtain data for modelling. The findings of water quality monitoring and surveys on the Athabasca River, 1990-93 were presented. Data collected prior to 1990 were also included for comparison. The effects of effluents were quantified and evaluated against AWQG and CWQG. Comparisons were also made with previous winter water quality surveys from 1988 and 1989. At the time of the study, three pulp mills discharged effluent directly into the Athabasca River. Other effluents to the Athabasca included municipal sewage from Jasper, Whitecourt, Slave Lake, Athabasca and Fort McMurray, sewage from Syncrude Canada Ltd., and oil sands wastewater from Suncor Inc. In the Athabasca River, effluent effects are usually greatest in winter, when dilution is lowest and ice cover restricts aeration. During higher flows in the open water season, effluent effects are much less pronounced. Similar effluent effects were seen in winter synoptic surveys during 1988 and 1989, although the later surveys indicated lesser effects than in previous years, suggesting improvements in effluent quality (Noton and Saffran 1995).

An overview of water quality, July 1972 to March 2001, examined conditions in the Muskeg River Basin (McEachern and Noton 2002). The Muskeg River and its tributaries have been sampled by Alberta Environment (AENV) between 1972 and 2001. During the periods from 1972-1975 and 1989 – 1997 sampling was limited to sites near the Muskeg River mouth. Enhanced monitoring at several sites occurred during 1976-1981, under the Alberta Oil Sands Environmental Research Program (AOSERP), and during 1997-2001 as part of recent work. The latter work has involved regular grab sampling of several sites, two synoptic surveys, and continuous recording meters installed at a range of sites. The purpose of the report was to summarize this data, interpret water quality conditions and controlling factors, check for any trends in water quality over the long term, and assess whether any effects of oil sands development are apparent. The intent was to make a scientific contribution to the knowledge and understanding of the Muskeg River system, and of potential oil sands development effects, in view of the level of development proposed for this basin (McEachern and Noton 2002).

The Muskeg River is a brown-water stream, typical of many in the boreal forest. Calcium and bicarbonate are the major ions, the water is somewhat alkaline and well-buffered, suspended solids and turbidity are low, dissolved organic carbon (DOC) and colour are high, and dissolved oxygen (DO) is low during winter ice cover. The extensive peatlands in the basin are the main source of DOC and are significant to the overall water quality of the Muskeg River. It appears that a majority of the streamflow comes from shallow groundwater sources. Much of this seems to be routed through organic soils, perhaps at the peat/mineral interface, which may account for the water being rich in minerals as well as DOC. Channel characteristics play an important role in modifying water quality. Phosphorus, DOC and suspended sediment concentrations decline in the low gradient reach of the Muskeg River due to biotic assimilation and sedimentation. Beaver ponds may be important in reducing nutrient concentrations, for example, total phosphorus. Dissolved oxygen (DO) is low in winter and below Alberta Surface Water Quality Guidelines (ASWQG (McEachern and Noton 2002).

Currently, the Muskeg River is not at risk of acidification. However, pH levels seem to be declining during recent years, for reasons that are not clear: a decline in mean pH from 7.8 in 1997 to 7.3 in 2001 has occurred; and pH seems to be largely determined by biotic processes in the stream channel.

Declining pH could indicate increased prevalence of reducing conditions, which in turn could be related to reduced stream flow in recent years. Both total phosphorus and total nitrogen concentrations were moderately high with maximum values typically 0.05 and 1.3 mg•L-1, respectively but have not changed appreciably since 1976. Occasional peaks in ammonia concentration (> 0.2 mg•L-1) occurred but fell within the ASWQG for the prevailing temperature and pH. High ammonia concentrations coincided in time with low oxygen conditions which may

reflect reduction (denitrification) of nitrate entering in groundwater or from decomposing organic matter. Total suspended solids concentrations were generally below 20 mg•L-1 and do not appear to be impacted in the Muskeg River. However, suspended sediment concentrations were elevated during winter months which may be a natural occurrence related to beaver activity and ice dynamics. The oxidation of suspended solids during winter may contribute to low dissolved oxygen concentrations under ice. In all cases except iron, metal concentrations were within the ASWQG. Iron has a large natural background source and can be expected to exceed ASWQG.. Based on studies of peatland systems in other regions, mercury is a concern because peatland drainage has the potential of causing mercury leaching to surface waters. AENV data from the Muskeg River do not indicate a problem with aqueous mercury, however, the dataset is small. The Alsands ditch contained elevated concentrations of the metals, barium, copper, iron, strontium, uranium and zinc compared to the Muskeg River. 'Trace organic' pollutants were rarely detected. When detected, polycyclic aromatic hydrocarbon (PAH) concentrations were below the ASWQG. Some PAH compounds were exported from the Alsands ditch, resulting in their detection at downstream sites. A full integration of data from all parties, as well as enhanced monitoring and investigations on the river system, would advance the understanding of its water quality and aid the protection and reclamation of the basin as development progresses (McEachern and Noton 2002).

To establish background levels of natural hydrocarbon release prior to new developments, various environmental samples were taken from selected tributaries in the oil sands region (see Figure 18) during 1998 through 2000, and analyzed by gas chromatography/mass spectrometry (GC/MS) for PAHs and their alkylated analogues. Samples were collected over 3 years to provide an increased understanding of the spatial distribution, nature and extent of natural hydrocarbon release to the environment. Results indicated that levels of total PAHs were elevated in the tributaries (up to 34.7 µg/g) compared to the main stem of the Athabasca River (< 2 µg/g). As expected, samples from the oil sands deposits contained the greatest amounts of PAHs and alkylated PAHs. Profiles of the alkylated PAH distributions were very similar, indicating that all the samples tested were from a common petrogenic source (Headley *et al.*, 2001).

This study was continued to determine whether the quality of water and sediments in tributaries of the Athabasca River are affected by flowing through reaches with exposure to natural oil sand deposits, in bed and suspended sediments collected from the MacKay, Steepbank, and Ells Rivers. A Mann-Kendall non-parametric analysis to assess the longitudinal trend of the metals in the bed sediments found no significant (α= 0.05) downstream trend in the MacKay or Steepbank rivers; however, the Ells River displayed a generally decreasing trend from upstream to downstream. The results provide no indication that metal concentrations in the bed sediments and/or suspended sediments of the MacKay, Steepbank, and Ells rivers increase significantly as the three tributaries flow through reaches that have natural oil sand exposures (i.e., in the McMurray Formation) (Conly *et al.*, 2007). Note that Headley *et al.* (2001) and Conly *et al.* (2007) sampled at the same sites (Figure18).

Sediments within and outside natural oil sand deposits were collected from sites along the Athabasca River. The ELS toxicity tests were conducted with control water, natural oil sands, reference sediments, and oil-refining wastewater pond sediments. Eggs and larvae were exposed to 0.05 to 25.0 g sediment/L and observed for mortality, hatching, malformations, growth, and cytochrome P4501A induction as measured by immunohistochemistry. Natural bitumen and wastewater pond sediments caused significant hatching alterations and exposure-related increases in ELS mortality, malformations, and reduced size. Larval deformities included edemas, hemorrhages, and spinal malformations. Exposure to reference sediments and controls showed negligible embryo mortality and malformations and excellent larval survival. Sediment analyses using gas chromatography–mass spectrometry revealed high concentrations of alkyl-substituted PAHs compared to unsubstituted PAHs in natural oil sands (220–360 mg/g) and oil-mining wastewater pond sediments (1,300 mg/g). The ELS sediment toxicity tests are rapid and sensitive

bioassays that are useful in the assessment of petroleum toxicity to aquatic organisms (Colavecchia *et al.*, 2004).

Water quality data on the Athabasca, Peace, and Slave Rivers at the boundaries of Wood Buffalo National Park between August 1989 and December 2006 were analyzed by Glozier *et al.*, (2009). Detailed statistical summaries for the period of record were provided, and patterns in water chemistry among the three watersheds were analyzed, including comparisons to upstream source waters. Parameters with national guidelines or site specific objectives for the protection of aquatic life were evaluated for excursions, including metals, major ions, and nutrients. Site-specific regression analyses for several parameters with suspended sediment concentration (as measured by NFR) were provided. Statistical temporal trend analyses (seasonal and yearly) were conducted for water quality parameter relationships to river discharge, specific time period, and season. More specific analyses were conducted to examine changes in metal and nutrient concentrations in the Athabasca River. Dissolved oxygen was lowest, while total dissolved solids and most major ions were highest in the Athabasca River compared with the Peace and Slave rivers. Trends in nitrogen concentration were similar in the Athabasca and Peace Rivers, and most dissolved forms displayed increasing concentrations. In both the Athabasca and Slave Rivers, dissolved and total phosphorus concentrations increased over the period of record. The increases in nutrient concentration observed were largely driven by increases during winter months, under conditions of low flow and ice-cover. Results showed that, at least in part, the concentration trends in the Athabasca River were related to the changing discharge regime. Increasing nutrients along with decreasing river discharge appeared to be a concern for the study reaches of the Athabasca and Slave Rivers (Glozier *et al.*, 2009).

Originally devised and overseen by Environment Canada, comprehensive monitoring in Alberta rivers was taken over by Alberta Environment in 1987, and is now referred to as the Long-Term River Network (LTRN). Initial sampling efforts on the Athabasca were limited to a single station at the Town of Athabasca. In 1977, a second site was established at Old Fort, 200 kilometres downstream of Fort McMurray. In more recent years, two additional LTRN sampling stations were created on the Athabasca River as a means of more effectively monitoring specific anthropogenic pressures, including forestry, pulp production, and resource extraction, on the river. These sites, situated upstream of both Hinton and Fort McMurray, were incorporated into the network in 1999 and 2002, respectively. Monthly sampling at these sites over an extended time frame provides high quality data for statistical trend assessment on some parameters. Monotonic trend analyses of water quality data revealed trends in several variables at both the Athabasca and Old Fort sites. Streamflow at both locations was found to be decreasing since 1960. At the same time, turbidity, a number of nutrients, and some metals described significant increasing trends at the Old Fort (downstream) station. Relatively high turbidity, in association with high nutrients and metals, is characteristic of the lower Athabasca River and its tributaries and has resulted in frequent water quality guideline exceedances for several variables. Increasing trends in these parameters, however, suggest an additional influence on water quality in the river. Decreasing flows and, hence, a reduced dilution capacity for point source effluents may be partly responsible. However, anthropogenic disturbance in the watershed may also be a contributor. At this time, further investigation would be required to establish causal links with any degree of certainty (Hebben, 2009).

1C: FURTHER WORK

- As the mandate for this report was to examine surface water quality and quantity, provincial groundwater monitoring programs and sites have not been covered. The importance of groundwater-surface water interactions is the subject of ongoing research. Current and historical groundwater studies and data sources could be important to the Integrated Monitoring Plan.

- Other relevant studies may exist, which have not been captured in this report. Further literature searches are warranted.

SECTION 2: MONITORING ANALYSIS

Many of the recent reports on the oil sands (e.g., Dowdeswell *et al.*, 2010, Lott andJones 2010, the Royal Society of Canada 2010, etc), include criticisms of monitoring performed in the area. For example, Kelly *et al.* (2009), Kelly *et al.* (2010) and Schindler (2010) raised serious questions regarding the adequacy and credibility of current environmental monitoring programs in the oil sands area. Donahue (2011) discussed government and RAMP monitoring in the area, and made suggestions on how to develop robust monitoring programs.

In September 2010, an independent panel of experts in the field of water pollution and its effects on aquatic systems was set up. The panel, called the Water Monitoring Data Review Committee, was instructed to review the articles by Kelly *et al.* (2009, 2010) and reports by Alberta Environment (Hebben, 2009) and the Regional Aquatics Monitoring Program (RAMP, 2009, 2010), examining study designs, data, and statistical approaches, to determine if the conclusions among these reports were consistent and comparable. The focused, short term sampling campaign used by Kelly *et al.* was adequate for estimating short-term inputs to the watershed in the region of the oil sands development and potential impacts to the aquatic ecosystem. The Alberta Environment study included monitoring at a limited number of stations, and was not specifically intended to determine impacts from the oil sands operations. The RAMP program has many monitoring sites, but the low sampling frequency each year limits this program's ability to determine impacts from oil sands operations (Dillon *et al.*, 2011).

A particularly important aspect to note is that potential temporal reference information depends on the availability of long-term data. This can usefully be considered from a minimum of 3-5 years (Reid and Ogden 2006). Many research studies do not extend beyond 2-3 years, therefore longer term monitoring may offer the best opportunity for temporal reference information. Long-term datasets are affected by changes in sampling frequency, methods, and laboratory detection limits, which must be taken into account when analyzing from trend (Glozier *et al.*, 2009).

2A: ANALYSIS OF MONITORING

2A1: GOVERNMENT MONITORING

2A1.1: Alberta Environment

Alberta Environment has three Long Term River Network sites downstream of the mineable oil sands area (see Figures 2 and 3).

On the Alberta Environment Surface Water Quality Data webpage is an 'Inventory' report. The Crystal Reports Viewer will provide an inventory of sites and data. The best way to run it is by selecting one sub-basin, and one type of station, at a time.

http://environment.alberta.ca/01288.html

Data are readily available upon request. The web portal is meant for general public consumption and represents only a limited component of what is actually available. Data requests can be made to Data Management.

This database will be an important resource for useful monitoring data. Data mining and evaluation will be a fundamental component of the monitoring design process. Historic as well as current data will be important to such aspects as power analysis, trend analysis, and evaluation of potential reference data.

2A1.2: Environment Canada

Environment Canada water quality monitoring downstream of the surface-mineable oil sands effectively consists of a single site, as the Slave River site is heavily influenced by the Peace River. The Athabasca River at 27th Baseline site, while originally set up to monitor for indicators of eutrophication, has recently increased parameters to include petrochemical indicators. Increases in petrochemical parameters are also being implemented in the Slave River site, on the downstream side of Wood Buffalo National Park, in cooperation with Alberta Environment. Data from this site, or any of the other Environment Canada long-term monitoring sites, are available on request.

Water quantity monitoring on the main-stem of the Athabasca River includes only two active and continuous gauges in operation. The gauge at the Embarras Airport site was discontinued in 1984 and only has annual flow records for the years 1972, 1973 and 1975. When comparing the annual mean flow for the three main-stem gauges during those years, it is possible to establish the relative contribution of the upper, middle and lower reaches to the overall flow (Figure 19).

In comparing the relative contributions of the Athabasca basin to the discontinued gauging site at Embarras Airport we observe the following: Station 07BE001, Athabasca River at Athabasca (upper reach), with a mean flow of 448 m^3/s, accounts for 57.4% of total flow. The drainage area for this site is 74,600 km^2 which is 48% of the gross drainage area (GDA) to Embarras Airport. Station 07DA001, Athabasca River below McMurray (middle reach), with mean flow of 718 m^3/s, contributes an additional 270 m^3/s for a total 91.6%. The gross drainage area to this site is 132,600 km^2 or 85.5 % of the GDA to Embarras. An increase in drainage area of 43% results in an increase of annual flow of 37%. At station 07DD001, Athabasca River at Embarras Airport (lower reach), with mean flow of 783 m^3/s, contributes an additional 8.2% of total flow. The GDA to this site is 155,000 km^2, an increase of 14.5% above the area to Fort McMurray.

Some preliminary suggestions for network enhancement with respect to water quantity monitoring may be proposed. The focus for network changes is on the lower reaches (downstream of Fort McMurray) based on the fact that most development in the mineable oil sands region occurs between Fort McMurray and the discontinued site at Embarras airport. The first suggestion is to increase the number of gauging sites in the area under development. Prior to the establishment of new sites or re-opening discontinued sites, it is important to review the goals of the network, the network as a whole, and the issues of accessibility, sensibility, and economy (below) that may have led to the decision to operate the current network. (Note that some sites were discontinued after a very short (1 to 2 year) operating period).

The following four considerations for establishing a stream gauge need to be satisfied.

- **Fulfillment:** Will the site satisfy a gap in the network? For example, if you want flow for the Bow River at Calgary, establishing a gauge on some other stream as a surrogate may not solve the network need.
- **Accessibility:** Is the site accessible? This needs to be considered a number of ways:
    - Physically accessible in a timely manner;
    - The land owner allows access;
    - Access to the gauge and to the measurement platform are safe for workers.

- **Sensibility:** The changing water level/flow rate is sensible to the gauging equipment deployed. For example, if there is an active beaver dam below the gauge site, rising stage may mean less flow.
- **Economy**: Is the network best served by employing this alternative?

The second suggestion would be to examine the feasibility of changing all tributary stations from seasonal to annual. The following five stations represent about 63% of the total drainage area in that region. The active stations 07DA006 Steepbank River near Fort McMurray, 07DA008 Muskeg River near Fort McMurray, 07DA018 Beaver River above Syncrude, 07DB001 MacKay River near Fort MacKay and 07DC001 Firebag River near the mouth (see Figures 5 and 6) are all seasonal stations. The third suggestion is to examine the remaining tributaries in the regions that historically have been gauged, to consider the usefulness of gauging to water quality monitoring, under the considerations indicated above (Greg MacCulloch, Water Survey of Canada, pers. comm.).

2A2: RAMP

RAMP underwent a peer review process in 2004 and again in 2010. Many of the same criticisms came out in both reviews (Ayles *et al.*, 2004; Burn *et al.*, 2011). RAMP includes a Technical Design and Rationale as part of its documentation (RAMP, 2009).

Challenges with the current RAMP design include:

- The program is vulnerable to how development occurs, with monitoring sites not added if a development has not been approved or an operator decides not to develop that site. Sites can be eliminated after three years of monitoring after the development occurs if no impact is detected. Sites are not necessarily located near areas where stressors could be anticipated; e.g., where discharge water is released, where tailings ponds leakage is suspected, where buffer strips along the streams are narrow or the slope steep and significant erosion during rainfall and snow melt expected. *In situ* project operators are not included in RAMP.
- The RAMP is not integrated with the on-site monitoring; without knowing what the on-site monitoring is showing with respect to releases, timing, location of discharges, etc. it is difficult to place the monitoring data into a broader context and to focus attention on parameters of interest.
- The program is costly with logistic costs high, involving significant helicopter time and other on-site costs. The program can be expanded but the challenge is to improve it in a cost effective way.
- Water quality monitoring is limited to four times a year, which is insufficient. Such monitoring can miss major events such as ice and snow melt in spring, with the massive runoff and surface erosion that can occur during this season; it also misses storm events. Furthermore, this monitoring may not fully capture the release of dewatering and other non-process water. The use of *in situ* recording devices such as YSI temperature and conductivity meters, automated water samplers, passive sampling devices, etc. could more regularly track the seasonal variability in water chemistry.
- Sensitivity analyses have not been conducted to assess natural variability and the number of years and sampling frequency required to detect trends of various magnitudes. For the Northern Contaminant Program (NCP), 15 or more years of monitoring are required to detect a small percentage change in a compound which is known to be degrading in the environment. Sensitivity analyses of the magnitude of effects that could be detected, mass balance and modeling estimates of what is entering the environment

(water, ground water, atmospheric pathways) could be used to refine monitoring design. Required sample size and frequency could then be calculated (and the costs for such studies).

- Environmental Impact Assessments and EPEA approval processes could be informative, if more effectively linked to monitoring.
- Drainage water releases are monitored as is groundwater and this information is reported to Alberta Environment. It is not synthesized in RAMP, but this information is also not readily available elsewhere.
- RAMP does not have flexibility to consider new pathways and issues of concern, i.e., dust and debris entering the tributaries and rivers from the barren landscape which has exposed layers of sediment deposited millions of years ago and over the millennia undergone little weathering – in contrast to surface soils. Nor is it designed to specifically measure deposition around the upgraders. While snow is monitored, it is from a volume perspective and to contribute to the hydrology program for water budgets (RAMP, 2009).
- RAMP does not integrate data to develop mass balance estimates of what is entering the tributaries, what is entering the Athabasca, and what is being carried downstream. In the absence of RAMP or some other program providing these estimates, impacts are hard to detect.
- Details of the RAMP program could be improved, including better replication and improved metrics on organisms such as fish, and, ideally, carbon and nitrogen isotopes.
- RAMP monitoring stops at the Athabasca River delta and is only based on water and sediments. Since the delta and western Lake Athabasca are depositional sinks (as is Mamawi Lake), key areas are being missed in the monitoring. Suspended sediment load, chemical constituents, and fate are uncertain. In addition a fundamentally poor understanding of flow and depositional patterns limits prediction of industrial accident impacts; i.e., would sediments become contaminated, where, and for how long?
- RAMP produces a large annual report yearly. There is, however, no annual reporting in the form of workshops. RAMP and other monitoring findings could be presented annually in a 2-3 day workshop which could be broadened to include research and other programs integrating water, air and terrestrial monitoring. In the absence of a monitoring workshop, information on ongoing activities and findings are not easily obtained, synthesized, or discussed, and new monitoring and research directions established.
- Monitoring is expensive in the study area. There is a need for more frequent monitoring and on-site studies to track short terms changes. (Marlene Evans, Environment Canada, pers. comm.).

2A3: CUMULATIVE ENVIRONMENTAL MANAGEMENT ASSOCIATION (CEMA)

The Cumulative Environmental Management Association (CEMA) is a multi-stakeholder group operating in the Regional Municipality of Wood Buffalo. Based in Fort McMurray, Alberta and operating for over 12 years CEMA is a non-profit association which employees a professional secretariat to coordination its world class research through its working groups on Land, Air, Water and Reclamation. CEMA is a key advisor to the provincial and federal governments committed to respectful, inclusive dialogue to make recommendations to manage the cumulative environmental effects of regional development on air, land, water and biodiversity. CEMA's main goal is to recommend management frameworks, best practices and implementation strategies that address cumulative effects on air, land, water and biodiversity to protect, sustain and restore the

environment and to be protective of human health (Cumulative Environmental Management Association (CEMA) website).

In the late 1990's, the Alberta Government took steps to initiate a strategy to address potential cumulative environmental effects in the oil sands region. In 1998, Alberta Environment led the creation of the Regional Sustainable Development (RSDS) for the Athabasca Oil Sands Area. The RSDS identified and prioritized 72 environmental issues within the oil sands region that should be studied in light of the projected growth (Cumulative Environmental Management Association (CEMA) website).

The Cumulative Environmental Management Association (CEMA), was formed as a stakeholder group, in partnership with Alberta Environment and Alberta Sustainable Resources Development, to address 37 of the RSDS issues. CEMA's main goal was to provide recommendations to Regulators on managing potential cumulative environmental effects using an array of environmental management tools such as environmental limits or thresholds. CEMA is organized into a number of Working Groups by topic, including the Surface Water Working Group (Cumulative Environmental Management Association (CEMA) website).

[Addendum: Reports from the Working Groups, as well as annual CEMA reports are now downloadable from the CEMA DMS Library (http://library.cemaonline.ca).]

2B: ASSESSING INORGANIC AND ORGANIC CHEMICAL CONSTITUENTS/CONTAMINANTS

2B1: NRCAN REVIEW OF OIL SANDS WATER TOXICITY

Canmet ENERGY – Natural Resources Canada commissioned a review of oil sands process water toxicity and its impact on aquatic environments, based on oil sands mining operations.

Bitumen is removed from oil sands using about 2 cubic metres for every cubic metre of oil sands processed. The oil sands process water (OSPW), or fluid waste tailings, is an aqueous suspension of sand, silt, clay, residual bitumen, and naphtha contained in large settling ponds, or tailings ponds. The OSPW is kept within project areas, although some escapes to ground and surface water. Contaminants in OSPW can be partially degraded by microorganisms, as demonstrated in reclamation wetlands constructed for research in the oil sands area. In terms of remediation, the role of microorganisms in detoxifying and facilitating primary productivity within OSPW-affected surface waters is an area of ongoing research. Algae can survive high levels of naphthenic acids and other contaminants found in OSPW. OSPW is acutely and chronically toxic to aquatic invertebrates. For further detail on impacts to other wildlife and aquatic life, see the report (Summit Environmental Consultants Inc., 2010).

The main toxic components of oil sands process water (OSPW) are naphthenic acids, PAHs, PACs, salts and ions, and metals. Naphthenic acids are known to be toxic to aquatic organisms, and are thought by some to be the most toxic components in OSPW. Three major analytical challenges exist for naphthenic acids: a reliable and specific method to quantify naphthenic acids in waters or other materials; a method to separate individual isomers; a method that would quantify each of the isomers in a sample (Summit Environmental Consultants Inc., 2010).

PAHs and PACs are a group of toxic compounds that may concentrate in sediments and can potentially be transferred through various levels of the food web. Major sources of PAHs in the lower Athabasca River drainage basin include the natural leaching of oil sands deposits where surface waters interact with oil sand formations, and fugitive emissions and dust from oil sands

operations. Contributions from seepage of oil sands tailings impoundments may be a minor source (Summit Environmental Consultants Inc., 2010).

While not considered individually as among the most toxic component of OSPW, elevated salinity in OSPW creates additional reclamation challenges for oil sands operators. Elevated salinity is an important limiting factor for vegetative growth; however, little is known about the potential effects on amphibians, invertebrates and fish in reclamation wetlands. Trace metals found in the aquatic environment in the oil sands region originate from natural and anthropogenic sources. Relatively few metals are generally considered to be of toxicological concern in relation to OSPW; however, the concentrations of a number of metals found or predicted in EIAs to exceed aquatic guidelines (based on CCME and Alberta criteria) include: aluminum, arsenic, boron, barium, cadmium, chromium, copper, iron, manganese, nickel, selenium, and vanadium. One of the information gaps about contaminants related to OSPW is the impact to ecosystems of all of the types of contaminants (organic and inorganic) in combination (Summit Environmental Consultants Inc., 2010).

The toxicity of OSPW materials is also linked to analytical challenges and constraints for some of those constituents, particularly organics (see subsection C1). A complementary approach to costly organic analyses may be initial screening use of EEM-style biomonitoring qualitative analyses which can selectively outline toxicity based on surrogate benchmark indicator aquatic species. Successes have been achieved in both the pulp and paper and metal mining sectors with an EEM-based regulatory-regime. EEM industrial expertise and experience from pulp and paper operations located in the Peace Athabasca could be a valuable resource to draw from.

2B2: ANALYSIS OF COMPOUNDS OF PARTICULAR CONCERN (COPC)

An AOSERP report on the construction of an overall toxicology research design (Jantzie *et al.*, 1979) envisioned orderly toxicology research in the air, water, land, and human research sectors of AOSERP. The interdisciplinary nature of many potential toxicants was noted. It was anticipated that, because of the lack of detection of acute problems caused by oil sands developments, problems would be of a chronic or long term nature. The nature and magnitude of existing (at that time) and proposed oil sands development waste streams within the AOSERP study area were reviewed, plus the results of studies on air quality, water quality, and toxicology available at that time. A 'Toxicological Index' (ranking system) was proposed to outline the toxicological significance of specific inorganic elements to mammals and aquatic organisms. The index provided a list of elements judged to be of environmental concern (Jantzie *et al.*, 1979). Interestingly, this large assessment of toxicology seems to have been restricted to inorganic substances.

Elements of concern from Great Canadian Oil Sands (GCOS, now Suncor) upgrading effluent (process waste effluent), and Syncrude mine depressurization water were listed under high, moderate or low toxicological index. The high toxicological index included mercury, cadmium, chromium, arsenic, copper, zinc, and cobalt. Moderate toxicological index elements from these outfalls included beryllium, aluminum, selenium, iron, silver, lead, nickel, titanium, manganese, and barium. Low toxicological index materials included calcium, potassium, magnesium, sodium, fluoride, vanadium, silicon, chloride and boron. Published analyses and calculated annual loadings of selected parameters in the GCOS upgrading process water and Syncrude mine depressurization water were presented. Probable interactions of oil sands wastes with biological groups in the AOSERP area, and proposed regional effects and/or local effects of the oil sands waste groupings were listed. The groupings included:

- emissions, high altitude and low altitude (considered to present regional effects risk to biological groups);
- wastewaters and effluents:

- mine depressurization water,
- overburden drainage water,
- extraction tailings,
- upgrading wastes (Great Canadian Oil Sands [now Suncor]),
- tailing pond seepage, and
- plant site runoff (Jantzie *et al*., 1979).

Most of the wastewaters and effluents were considered to present risk of local effects to biological groups. Regional effects were considered possible, but difficult to predict. High-index substances of concern for mammals were listed as arsenic, beryllium, thallium, cadmium, copper, and mercury. Similarly, high-index substances for aquatic organisms were listed as cadmium, mercury, arsenic, copper, chromium, zinc, and cobalt (Jantzie *et al*., 1979).

Appendix 2 summarizes COPC listed and analyzed in ten open-pit oil sands Environmental Impact Assessments (Fort Hills True North 2001 through Jackpine Mine Expansion/Pierre River Mine 2007). These substances were deemed to be of concern due to projected elevations in certain waterbodies, in terms of potential cumulative effects, or as known toxins. Substances included aluminum, ammonia, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chloride, chromium, cobalt, conductance, copper, dissolved organic carbon, iron, lead, magnesium, manganese, mercury, molybdenum, naphthenic acids – labile, naphthenic acids – refractory, naphthenic acids – total, nickel, nitrate + nitrite, PAH groups and PAH (total), potassium, selenium, silver, sodium, strontium, sulphate, sulphide, tainting potential, total dissolved solids, total nitrogen, total phenolics, total phosphorus, toxicity – acute, toxicity – chronic, vanadium and zinc.

2B3: GUIDELINES ANALYSIS

It is important to note that Environmental Quality Guidelines (EQGs) provide benchmarks for the quality of the environment. Where an EQG is met for an environmental variable there is little probability of adverse effects on protected use (e.g., aquatic life or the wildlife that may consume them). Where an EQG is exceeded, there is an increased probability of adverse effect, but further site-specific information would be required to confirm whether or not an adverse effect is actually occurring. EQGs are based on the toxicological effects or hazard of specific substances or groups of substances and do not take into account analytical capability or socioeconomic factors. Use of EQGs is voluntary unless prescribed elsewhere (e.g., through regulation). EQGs are not effluent limits, but may be used in their derivation. Rather they serve three functions: first they can be an aid to prevent pollution by providing targets for acceptable environmental quality; second they can assist in deciding the significance of concentrations of chemical substances currently found in the environment (monitoring of water, sediment and biological tissue); and third, they can serve as performance measures of the success of risk management activities (Canadian Council of Ministers of the Environment, 2011a).

Alberta Water Quality Guidelines can be used as tools to support the Environmental Protection and Enhancement Act. They provide general guidance in evaluating WQ in Alberta. They are also used in setting water quality-based approval limits for effluents (Alberta Environment 1999)

The list of compounds in Table 3 was compiled from oil sands mining project Environmental Impact Assessment (EIA) reviews (see Appendix 2). The related CCME Chemical Name reference comes from the Canadian Environmental Quality Guidelines (CEQG) - Summary Table (Canadian Council of Ministers of the Environment 2011b and c).

A cross-reference table of these COPCs with applicable water or sediment quality guidelines can be found in Appendix 3. Sources:

Canadian Council of Ministers of the Environment (2011a, b and c)

http://www.ccme.ca/publications/ceqg_rcqe.html

http://ceqg-rcqe.ccme.ca/

http://st-ts.ccme.ca/

Alberta Environment (1999, 1995-2011)

http://environment.alberta.ca/01322.html

http://environment.alberta.ca/01323.html

United States Environmental Protection Agency (2009, 2011)

http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/index.cfm

http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm

Table 3: Oil Sands Compounds of Specific Concern compiled from Environmental Impact Assessments, for which No Water Quality Guidelines Exist.

Compounds of Specific Concern – Compiled from OS mining EIAs		CCME Chemical Name
	PAH 8	2-Methylnaphthalene
	PAH 4	Acenaphthylene
3	Antimony	Antimony
5	Barium	Barium
	PAH 2	Benzo(b)fluoranthene
	PAH 2	Benzo(k)fluoranthene
6	Beryllium	Beryllium
	PAH 6 biphenyl variations	
9	Calcium	Calcium
	PAH 3	Chrysene
13	Conductance	Conductivity
	PAH 1	Dibenz(a,h)anthracene
15	Dissolved Organic Carbon	
	PAH 2	Indeno(1,2,3-c,d)pyrene
18	Magnesium	
19	Manganese	Manganese
22	Monomer	
24	Naphthenic Acids – Refractory	
25	Napthenic Acids – Total	

Compounds of Specific Concern – Compiled from OS mining EIAs		CCME Chemical Name
27	Nitrate + Nitrite	Nitrate + Nitrite (*CCME revising Nitrate)
39	Potassium	
42	Sodium	Sodium
43	Strontium	
44	Sulphate	Sulphate
46	Tainting Potential	
47	Total Dissolved Solids	Total dissolved solids (salinity)

Other parameters may have existing guidelines, but those guidelines may not be effective or applicable to a high-sediment rivers like the Athabasca. For example, some metals guidelines are not particularly applicable in the Athabasca, because of the high sediment load (Glozier *et al.*, 2009).

Compounds of Particular Concern in the oil sands area that do not currently have guidelines should be targeted for urgent further research toward development of guidelines.

2C: IDENTIFY AND ASSESS CURRENT ANALYTICAL CHALLENGES AND CONSTRAINTS

2C1: ASPECTS OF HYDROMETRIC DATA TO CONSIDER: REVIEW OF HYDROMETRIC RESULT ACCURACY IN THE ATHABASCA BASIN

Hydrometric data as produced by the government of Canada is for the most a time series of water level data in lakes, reservoirs, streams, and canals. The network of gauging sites was designed to provide water level and streamflow data to be used for water supply estimates, water management, apportionment, and risk management (flood and drought) decision making.

Assessing the quality of hydrometric results is not an easy process. The first consideration is that there are several kinds of data in the results and the uncertainty varies according to the type of derivation employed to achieve the reported result.

Hydrometric Data Derivation Types:

- Annual Total Volumes (dam^3)
- Annual Instantaneous Maximum flow rate (m^3/s)
- Annual Mean Daily Minimum flow rate (m^3/s)
- Mean Daily flow rate (m^3/s)
- Mean Daily Water level (m)
- "Instantaneous" Direct Discharge measurement (m^3/s)
- Post Facto – Indirect Discharge measurement (m^3/s)
- Instantaneous Water level reading (m)

To access the quality of the hydrometric derivations, the first consideration is the various quality measures; i.e., accuracy, precision, error, and uncertainty.

In simple terms the quality measures can be defined as follows:

- Accuracy: how well the result agrees with the accepted standard,
- Precision: the repeatability of the result regardless of the correct value,
- Error: the difference between the result and the accepted value.
- Uncertainty: the range within an expected result which may occur.

To understand how well the hydrometric result conforms to these quality measures, it must be understood how each of the results is derived, and the results must be compared to accepted standards.

For some aspects of the derivations there are standards for comparison. For example lineal measures such as stage, width, depth etc. can be demonstrated to be measurable to ±1% of scale and mechanical velocity meters can be demonstrated to be within ± 2% of scale for turbine velocities in excess of 1 revolution/sec. Mean velocities observed during direct discharge measurements for the main stem Athabasca River are well within the acceptable operating range for the Price AA current meter; similarly, widths and depths of the individual velocity panels are large enough to assume errors in the length dimensions are small and that the accumulated measurement error for the measurements are within the ±5% range commonly accepted for mechanical current meter measurement.

Apart from the direct discharge measurements, streamflow determinations are not well suited for such measures as accuracy and precision of the result, as the relationship between the measure (typically time varying stage) and the hydrometric result (mean daily volumetric flow rate) changes according to the hydraulic capacity of the stream channel, which is impacted by changes to rate of flow, ice, aquatic vegetation, bed changes (aggradation, degradation), and other factors. Frequent calibrations to the relationship are often required and the time between calibration measurements is a factor in the uncertainty of the result.

For derivations such as mean daily discharge rates and other derivatives of flow rate there are no standards to measure against and some level of uncertainty must be assessed.

The best opportunity available to evaluate the uncertain in the hydrometric results is likely the comparison of results for two sites that were operated coincidentally from 1973 to 1984 in the lower portion of the Athabasca basin.

The Lower Athabasca behaves as an "exotic" stream in that the relationship between drainage area and basin yield is not well defined. A comparison of two sites along the mainstem (Athabasca at Athabasca and Athabasca at McMurray) as shown in Table 4, demonstrated a 21% difference in drainage area but only a 9% increase in basin yield during median years. During the maximum flow year the increase in yield is comparable to the increase in drainage area, suggesting that only in extreme years does the whole basin below the town site of Athabasca contribute.

Table 4: Discharge and drainage areas.

Flow station	Drainage Area (km^2)	Annual total discharge (dam^3)		
		Minimum (Year 2002)	Median (Year 2007)	Maximum (Year 1997)
Athabasca River at Athabasca	74,600	8,708,835	13,981,633	19,373,126

Clearwater River at Draper	30,800	2,638,682	3,529,941	5,308,269
Sum upstream Sites	105,400	11,347,517	17,511,604	24,681,396
Athabasca River below McMurray	133,000	11,354,688	19,216,483	31,918,234
Difference:	27,600	7,171	1,704,879	7,236,838
Difference (%):	21%	0.1%	8.9%	23%

Keeping in mind the exotic nature of the main stem of the Athabasca River in this part of Alberta, uncertainty in stream discharge determination is demonstrated by the coincident record for the site at the Athabasca at McMurray and the Athabasca River at Embarras Airport, which is approximately175 km downstream.

Hydrometric ratings for large streams such as the Athabasca River are well defined. Nevertheless, confidence in establishing daily discharge values relies on some degree of subjectivity. The greater the time lapse between direct discharge measurements, the greater the uncertainty of the result. A review of the measurements in the area shows that the mean time between measurements has changed over time. During the period from 1971 to 1977, there was an average of 57 days between direct discharge measurements. From 1995 to 2008 the time between measurements has increased to 98 days.

Looking at direct discharge measurements when both gauges were operating: Figure 20 demonstrates that when the measurements are taken at approximately the same time that the values obtained at the downstream site are on average less than the values at the upstream site (about 95% of the upstream values). Most measurements fall between ± 15% of the 95% line; which gives some measure of the uncertainty of the result. Intuitively, similar or greater values would be expected downstream, but on average coincident flow measurements were less at the downstream site.

In contrast, the daily result, as demonstrated in Figure 21, shows that on average the downstream site produces between 6% and 7% more water. Again, the uncertainty in the relationships between the mean values is in the 15% range with most values falling between ± 15% of the average difference between the two gauging sites.

One problem with the hydrometric result was the use in the late 1970's and early 1980's of the Streamflow Accounting Program (SAP) which was used to ensure downstream gauge results were always greater in magnitude than their upstream components. The model made the assumption that all streams accumulate flow in proportion to their increase in drainage area. Even without application of this aid to streamflow determination the technician was directed to always show more water at a downstream gauge.

The analysis of the uncertainty in daily streamflow determinations must consider that there is a degree of subjectivity in the result. As shown, when confronted with the direct measurement data that shows on average a reduction in flow by 5% the daily result for the period reviewed has an average increase of 7%.

This cursory analysis shows that daily mean discharge determinations are somewhat subjective. Measurable parameters such as mechanical current meter determinations of flow rate are likely in

the ±5% range for velocities in excess of 1 revolution per second. However, the frequency of such observations is in decline.

The comparison of charts of the direct measurements at these two sites suggests that an uncertainty of derived daily mean flows are expected to be similar to ± 15% and that this number is representative of the level of uncertainty in any daily determination in comparable geography.

The fact that the daily results for the downstream site were not determined independently of the upstream site adds to the uncertainty in the final values at the downstream site (Greg MacCulloch, Water Survey of Canada, pers. comm.).

2D: REGULATORY AND PERMIT COMPILATION, WATER QUALITY AND QUANTITY

2D1: ENVIRONMENTAL EFFECTS MONITORING, PULP AND PAPER MILLS

Environmental Effects Monitoring (EEM) detects and measures changes in aquatic ecosystems. The EEM requirement under the Pulp and Paper Effluent Regulations (PPER) is a science-based performance tool used to help assess the adequacy of the PPER to effectively protect fish, fish habitat and the use of fisheries resources by humans. The Pulp and Paper EEM consists of an iterative system of monitoring and interpretation phases designed to evaluate the effects of a mill's effluent on these aquatic resources. There are four pulp and paper mills that conduct EEM in the Athabasca River. Sampling generally takes place in areas directly upstream (reference area) and downstream (exposure area) of each facility's effluent discharge point. Exposure areas may include both near-field and far-field sites, which can range in location from less than 1 km downstream to over 100 km downstream of each effluent discharge point. Facilities are encouraged to sample the same general locations during each monitoring phase. Water quality data is collected to support the interpretation of EEM results. The water quality monitoring and reporting requirements under the PPER can be found in Schedule 4, Section 9 of the Regulations

(http://laws.justice.gc.ca/en/showtdm/cr/SOR-92-269//?showtoc=&instrumentnumber=SOR-92-269).

Figure 22 identifies sampling locations that correspond to data these mills have submitted to Environment Canada in EEM reports. The parameters measured are included in Appendix 1. Water quality data collected by the Alberta pulp and paper mills under the PPER EEM requirements could be used as geographic and/or temporal reference data, in comparison to monitoring data from the oil sands area. This concept was also suggested in Lott and Jones (2010). Further, Fisheries Act-related EEM program information from pulp and paper operations located in the Peace-Athabasca area could be useful for oil sands operators.

D2: ALBERTA WATER ACT AND ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT APPROVALS

On-site monitoring, and monitoring of specific outfalls and effluents, falls under the jurisdiction of the Alberta Environmental Protection and Enhancement Act. Once projects have passed through the environmental assessment process, EPEA Approvals are written for on-site monitoring requirements. Details of monitoring requirements are specified in each EPEA Approval for each project; however the specific locations of that monitoring are currently only available in hard-copy reports submitted to Alberta Environment Pat Marriott, Alberta Environment, pers. comm.).

2D2.1: Alberta Water Act licensing and approvals

The Water Act provides the following authorization and notification processes for activities and diversions of non-saline water. These authorization processes are described in the Water Act Approvals and Water Act Licences tables respectively. Water Act Approval: required for any activity that could affect water management, including those that disturb, or may disturb surface water (i.e., construction in, on, under, in some cases over, or adjacent to water bodies) or water below the surface [groundwater] [i.e., water well drilling, or excavations that does or may affect groundwater]), subject to some exemptions. Water Act Licence: required for all diversions (e.g., withdrawals, storage) of non-saline water, subject to some exemptions (Alberta Energy Resources Conservation Board website).

Ownership of all water in Alberta is vested in the Crown and therefore permission from the Crown is required prior to diverting or using water. Under the Water Act, water is allocated and managed based on "first in time, first in right." Water Act licences provide the means for establishing an applicant's priority in the 'queue' to divert water from a specific water source.

Licences under Alberta's Water Act are required for most water diversions (including surface or non-saline groundwater). Under the Water (Ministerial) Regulation "saline groundwater" means water that has total dissolved solids exceeding 4 000 milligrams per litre. Diversions of water for hydrostatic testing of pipelines are exempt from Water Act licences when the code of practice for those diversions is followed and adequate notice is provided. Other diversions such as for dust control and making drilling fluid for wells on public land are exempt from Water Act licences under specific conditions set out in the Water (Ministerial) Regulation (Alberta Energy Resources Conservation Board website).

2D2.2: Alberta Environmental Protection and Enhancement Act approvals

Under the Activities Designation Regulation of the Environmental Protection and Enhancement Act some upstream oil and gas activities require an authorization through a notice, registration, or approval. Under Environmental Protection and Enhancement Act's Environmental Assessment (Mandatory and Exempted Activities) Regulation some activities require an environmental assessment prior to being considered for an Environmental Protection and Enhancement Act authorization. The following are the processes followed: Authorization - the schedules of the Activities Designation Regulation designate which activities require an authorization under the Environmental Protection and Enhancement Act. The authorization process follows requirements of the Approvals and Registrations Procedure Regulation (AR 113/93). Environmental Assessment is the first step in a regulatory process that examines a project to determine what the environmental, social, economic and health implications may be and gathers information on the project and determines specific conditions under which the project can operate. The process is generally applied to complex, large scale activities that may have the potential to result in environmental, social, economic and health impacts (Alberta Energy Resources Conservation Board website).

The purpose of an Environmental Protection and Enhancement Act Approval is to "support and promote the protection, enhancement and wise use of the environment...". Schedule 1 of the Activities Designation Regulation specifies activities that require Environmental Protection and Enhancement Act Approvals. Some examples of activities designated under the Activities Designation Regulation of the Environmental Protection and Enhancement Act, as requiring an approval include: Sour gas plants, wastewater management and potable water systems, brine storage ponds, hydrostatic test water releases, sulphur storage facilities, sulphur manufacturing

or processing plants, syngas plants, power plants, transmission pipelines, and oil sands processing plants. General provisions of the Environmental Protection and Enhancement Act also apply (Alberta Energy Resources Conservation Board website).

These EPEA approval requirements indicate that there is a wealth of on-site data and information relevant to monitoring design in the oil sands area. Mining these approvals for monitoring locations and data will be an important step in any data compilation and analysis, in the area.

Key stressors for the Peace and Athabasca river basins were summarized in the NRBS Synthesis Report 11 on cumulative impacts (Wrona *et al.*, 1996). Major point source effluent discharges were identified in the NRBS Synthesis Report 3, on distribution of contaminants in the Peace, Athabasca and Slave River basins (Carey *et al.*, 1997). The location, treatment technology and waste disposal methods of all licensed municipal and other (excluding pulp and paper mills) effluent dischargers in the Peace, Athabasca and Slave River basins were summarized for the NRBS program by SENTAR Consultants Ltd. (1996). Some of this information may be out of date, and an updated summary of EPEA licensing information, particularly for the surface-mineable oilsands area, is needed.

Provided below (see Appendix 4 for further detail) is a summary of discharge locations (mostly dewatering waters), approval requirements and water monitoring activities by the various proponents as extracted from current (2010) EPEA approvals documentation. Figure 23 indicates the location of industrial outfalls that have been identified, but should not be considered complete or permanent, as sewage outfalls have not been identified, and dewatering activities are not static. Dewatering processes change as mine plans advance, so the information here will only be accurate for a limited time.

Specifics of what is monitored at which sites can vary among facilities (see Appendix 4). In general terms, dewatering waters are usually monitored for parameters such as flow, pH, total suspended solids, and acute lethality bioassay (frequency varies among facilities).

Some facilities monitor dewatering waters for chemical oxygen demand, nutrients, major ions, DOC and DIC, 5 day biochemical oxygen demand, total recoverable and total dissolved metals including ultra-trace mercury, ammonia, dissolved oxygen, chronic bioassays, oil and grease.

As well, EPEA requirements may call for

- hydrocarbons (specifics vary, see Appendix 4),
- Inorganic CCME: All inorganic parameters, except chlorine and nitrosamines, listed in the Guidelines for Freshwater Aquatic Life of the Canadian Water Quality Guidelines, CCME, 1988, as amended (Canadian Council of Ministers of the Environment, 2011b and c);
- Full suite: Biological oxygen demand, dissolved organic carbon, benzene, toluene, ethyl benzene, xylene (BTEX), chemical oxygen demand, chloride, colour, naphthenic acids, oil & grease, phenols, polyaromatic hydrocarbons, sulphate, total phosphorous, total dissolved solids, temperature, total sulfide, total suspended solids.

SYNCRUDE Operations: Mildred Lake oil sands processing plant and mine, Aurora North oil sands processing plant and mine, and Aurora South oil sands processing plant and mine

The approval holder is required to monitor Mildred Lake plant industrial wastewater, Aurora North plant sedimentation pond and the Muskeg River. Figure 23 shows a discharge point at west interceptor ditch (referred to as WID discharge point) into Bridge Creek which collects clean surface water that is north of the active mine footprint and north of Mildred Lake settling basin. Mildred Lake system also has a domestic sewage discharge indicated in the EPEA approvals but not on Figure 23. The approval holder directs muskeg dewatering and other water resulting from clearing of the west side of the Aurora North Plant towards Mills creek and into the Athabasca

River. There are two main sedimentation ponds at Syncrude Aurora. The first is the 1-05 Centre Pit Polishing Pond, and the second is Puhalski's Polishing Pond (see Appendix 4). The water is discharged to the diversion outlet. Syncrude has two discharge points on Stanley creek, one at the diversion inlet and the other at the outlet. They correspond with the Stanley Creek Diversion Pipeline input and output locations. Each discharge point has a stilling well where the released water flows into before it enters the creek. Both wells receive water from sedimentation ponds and from the East Mine Seepage Curtain. Water sampling locations on the Muskeg River are shared with RAMP.

IMPERIAL OIL Operations: Kearl oil sands processing plant and mine.

The approval holder is required to monitor sedimentation ponds. No specific creeks or waterways are mentioned as release points from the sedimentation ponds within the EPEA documentation. Releases are assumed as follows:

- Polishing pond 1 releases directly into the surrounding muskeg adjacent to two ditch plugs.
- Polishing Ponds 2 and 3A release into what are labelled salvaged streams. These are overland releases.
- One additional release point exists at the end of the drainage ditch near site A-RWI-1 into the unnamed stream.

Imperial Oil is currently implementing an overland release strategy for Pond 1, Pond 2 and Pond 3A.

Pond PDP is located in the remote area and will become an unmanned facility after the raw water intake construction is complete. Overburden pond is a tiny settling pond for the construction of the compensation lake. Parameters are listed in Appendix 4.

SHELL CANADA LIMITED Operations: Jackpine Mine.

Muskeg dewatering, overburden dewatering and overburden disposal area drainage shall be directed to sedimentation ponds, except for overburden water removed by wells. Monitoring sites are clearly identified for sedimentation ponds 2, 3, 6 and 4 at the outlets of each of the ponds prior to them reaching the receiving waterbodies (see Figure 23).

Discharges, all referred to as site A, are from the finishing ponds as follows:

- Pond 3 discharges to Jackpine Creek;
- Pond 6 discharges to Jackpine Creek;
- Pond 2 discharges to Shelley Creek;
- Pond 4 discharges to Khahago Creek.

Parameters are listed in Appendix 4.

ALBIAN SANDS ENERGY INC (SHELL CANADA ENERGY) Operations: Muskeg River Oil Sands Processing Plant and Mine.

The approval holder is required to monitor sedimentation ponds.

Three types of monitoring sites for sedimentation ponds and Muskeg River system (A, B, and C):

- A is the discharge point of the sedimentation pond prior to mixing with the Muskeg River.
- B is the receiving stream, Muskeg River, upstream of seepages and discharges.

- C is the receiving stream, Muskeg River, downstream of seepages and discharges.

No information on the location of the discharge points is provided. Some shared RAMP sites are indicated. Other than the text description, no coordinate information is available, therefore no release points for this operation have yet been mapped.

SUNCOR Operations: Oil Sands processing plant and mine which includes the Base Mine, Steepbank/Millennium, North Steepbank Extension, and Voyageur.

The approval holder shall only release industrial wastewater and industrial runoff to the Athabasca River watershed. Note that the two release types (dewatering waters and industrial wastewater) are both included in the EPEA approvals list and are difficult to distinguish from each other. Based on the maps and approvals the following release points have been identified:

- the Pond C Duckpond; (industrial wastewater);
- the Pond E Duckpond; (industrial wastewater);
- Mid-Plant Drainage (Weir #10); (runoff);
- North Mine Drainage (Weir #7); (runoff);
- South Mine Drainage (Weir #1); (runoff);
- Pond R;
- Pond A East;
- McLean Creek Wetland Runoff Pond;
- One of the following three outfalls:
    - North Steepbank Extension - Unnamed Creek outfall NS_OF_01;
    - North Steepbank Extension - Unnamed Creek outfall NS_OF_02;
    - North Steepbank Extension - Unnamed Creek outfall NS_OF_03;
    - Voyageur Upgrader (VU) – Borrow Pit (VU_SED_01);
    - Voyageur Upgrader - West Temporary Settling Pond (VU_SED_02);
    - Voyageur Upgrader - Permanent Sedimentation Pond (VU-SED_03);

Parameters are listed in Appendix 4. Both the Pond E and the Pond C discharges, in the Base Mine facility, are active industrial wastewater outfalls. The Pond C discharge includes blowdown, softener brine and RO (reverse osmosis) reject from the freshwater treatment plant, wastewater from API (oil) separators (both upgraders) and wastewater from the coke settling ponds. Average volume is 3,330 gpm. The Pond E discharge is wastewater from the flue gas desulphurisation (i.e. flue gasses pass through lime scrubber, which gives gypsum and other material) settling ponds. Average volume is 1,400 gpm. Suncor proposes to double the discharge volume (7,705 gpm) but to treat the Pond C discharge by dissolved air floatation (flocculant added, floated off by bubbling) (Rod Hazewinkel, Alberta Environment, pers. comm.).

The industrial wastewater release from Suncor is much more stringently monitored, as it is a true effluent (see Figure 23). An AOSERP study evaluated the constituents of wastewaters from the Suncor (then, Great Canadian Oil Sands) upgrader (Strosher and Peake 1976). As well as the types of parameters monitored in dewatering waters, discussed above, although at a much greater frequency than is normally required in the dewatering outfalls, the industrial wastewater is checked for phenols, ammonia and other constituents (see Appendix 4).

More dewatering releases for the Suncor Voyageur site are expected in the future. The East Tank Farm holding pond is mapped in EPEA documentation but it is not clear where the release, if any, is located. AENV confirmed that runoff is managed here through a "wheel run" system.

There are 4 small runoff ponds in the Steepbank bridge area. Two of them on the west side of the bridge are currently released to the Steepbank River. The other two ponds on the east side of the bridge are currently pumped to the Steepbank Mine Extension Drainage system.

CANADIAN NATURAL RESOURCES LIMITED Operations: Horizon Oil Sands Processing Plant and Mine.

The approval holder is required to monitor the sedimentation ponds. The likely discharge location for the Horizon sedimentation pond for this operation has been identified. This discharge is a combination of discharge from two sedimentation ponds; DD7 plus is an existing waterbody modified for use as a sedimentation pond. Both sedimentation ponds are connected by a ditch and drain at the point indicated on the map (Figure 23). Parameters are listed in Appendix 4.

TRUE NORTH ENERGY L.P. [now Suncor] Operations: Fort Hills Oil Sands Processing Plant and Mine.

Accurate locations for all of the discharge and discharge overflow locations were provided directly from Fort Hills via EPEA contacts. As per the EPEA approval, industrial runoff from muskeg dewatering, overburden dewatering, and drainage from overburden (except for the overburden at the OPTA) and reclamation material storage area shall be directed to sedimentation ponds or the industrial wastewater control system for use as recycle water.

Those ponds which are operational vs. those non-operational have been identified, based on the documentation provided. Monitoring is done at all sedimentation ponds throughout the release period.

- Pond 1 discharge (operational)
- Pond 2 discharge (operational)
- Pond 4 discharge (operational)
- Pond 14 discharge (operational)
- No net loss lake (NNLL) discharge (operational)

Parameters are listed in Appendix 4.

2D3: Outcome Task – candidate core parameters for consideration in the monitoring design

Outcome task: suggest candidate core parameters for consideration in the monitoring design.

Proposed routine parameters:
Nutrients: Dissolved phosphorus, total phosphorus, dissolved nitrogen, total nitrogen, nitrate, nitrite, total ammonia, dissolved organic carbon, particulate organic carbon & nitrogen
Major ions: Ca, Mg, Na, K, Cl, F, SO_4, SiO_2, Alkalinity- Total
Total Suspended Solids, Total Dissolved Solids
Total and dissolved metals:Ag, Al, As, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, La, Li, Mn, Mo, Nb, Ni, Pb, Pt, Rb, Sb, Se, Sn, Sr, Tl, U, V, W, Y, Zn

Turbidity
pH, specific conductivity
Ultra-trace Hg, total
Priority PAH's (parent & alkylated)
Naphthenic acids
Isotopes ^{18}O and ^{2}H as part of normal sampling
Acrylamide monomers
Polyacrylamide
Gypsum
[Also consider isotopes ^{13}C, ^{14}C, ^{15}N, ^{34}S and components of same where found in sulphate/sulphide, nitrate/nitrite, gypsum].

2E: FURTHER WORK:

- Alberta Water Act and EPEA Approval reports for sampling site locations and information about on-site monitoring are very important in informing the oil sands area monitoring design. As mine plans proceed, the locations of dewatering outfalls and other EPEA-regulated activities will change. The information provided in this report is current to 2011, but should not be assumed to be static.
- Locations and details of EPEA approvals for sewage outfalls from work camps are not captured.
- Laboratory methods and detection limit changes, in current and historical information (data steps which may affect future comparisons/trend analysis) would be useful to have in a database or other collection medium, for future reference. Tracing this information would be a very large and time-consuming task.

  Editor's Note: The Cumulative Environmental Management Association (CEMA) has recently made its reports available on-line. There may be a number of valuable surface water quality and quantity studies now accessible through that library.

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FIGURES

Figure 1: Oil sands areas and land leases in Saskatchewan and Alberta.

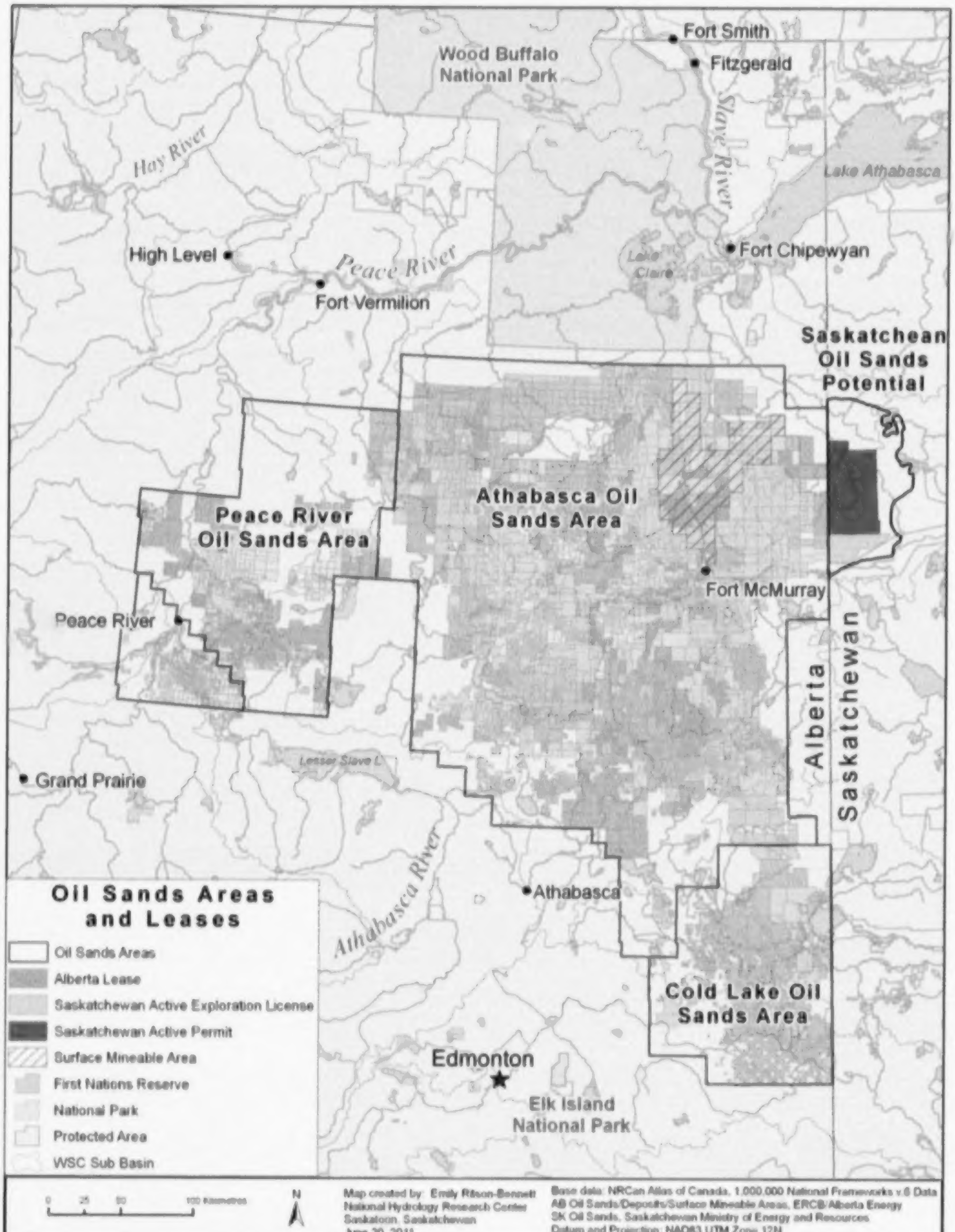


Figure 2: Major oil sands developments north of Fort McMurray.

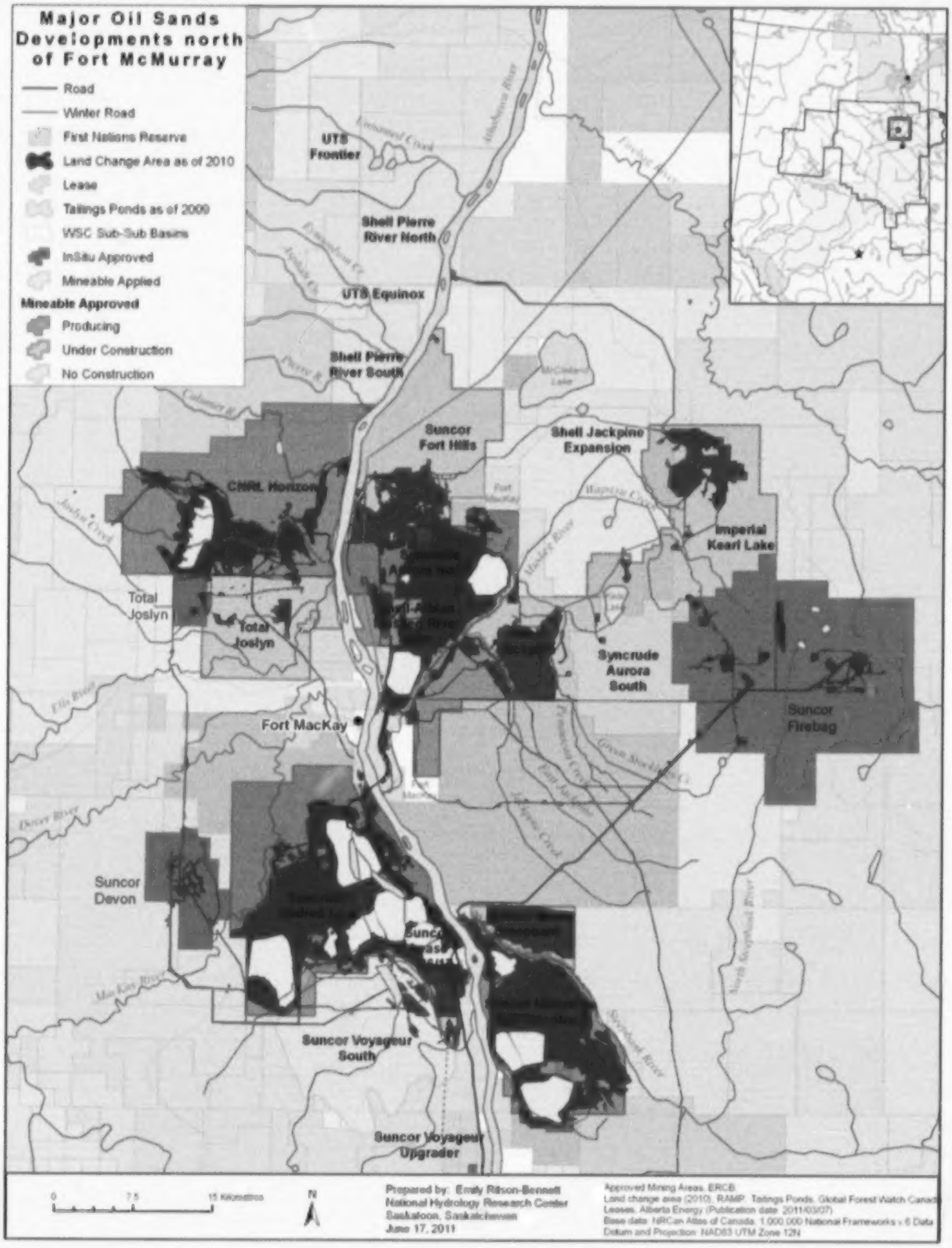


Figure 3: Long term Alberta Environment and Environment Canada water quality monitoring stations in the Athabasca Basin, Alberta.

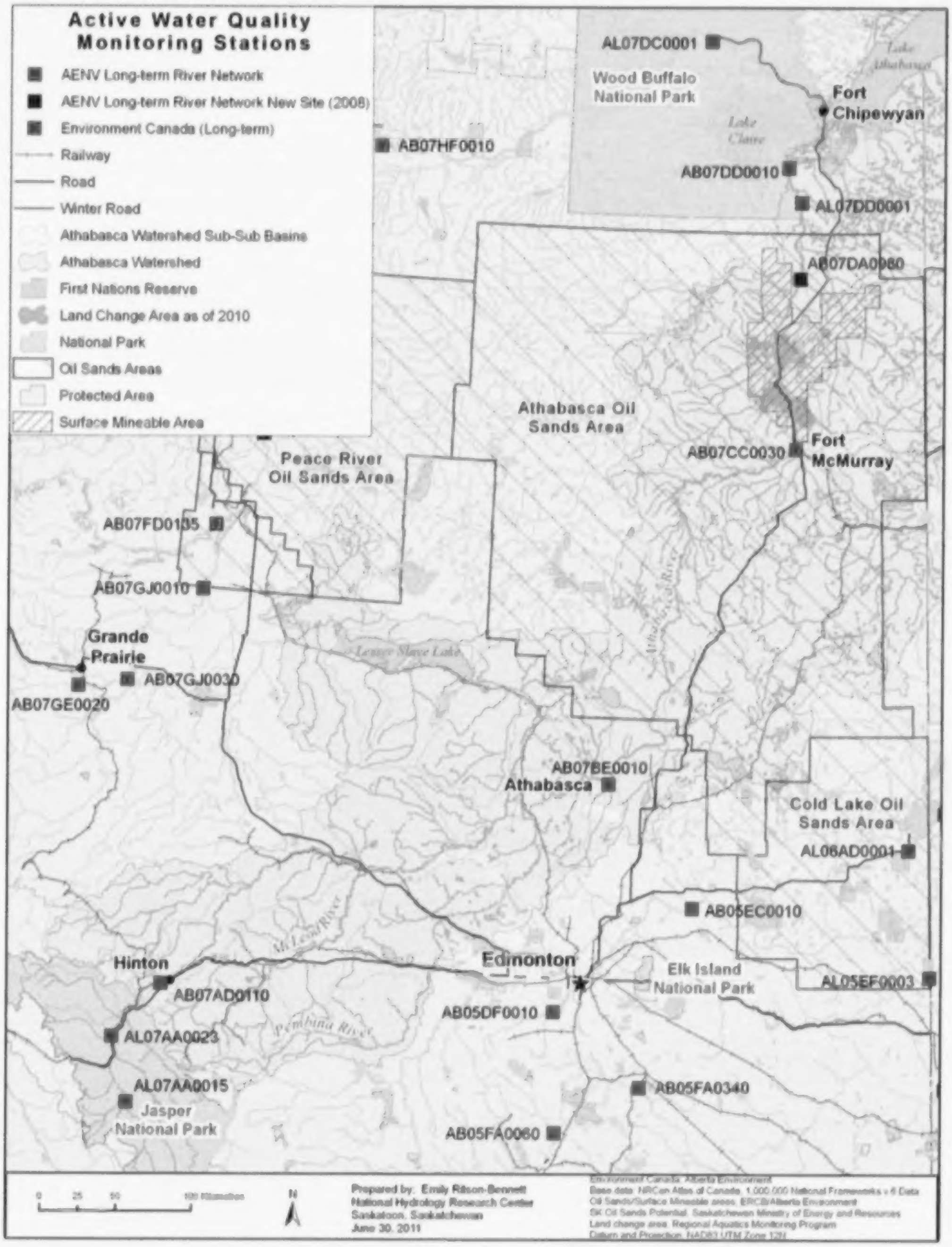


Figure 4: Long Term Alberta Environment and Environment Canada water quality monitoring stations in the Lower Athabasca area.

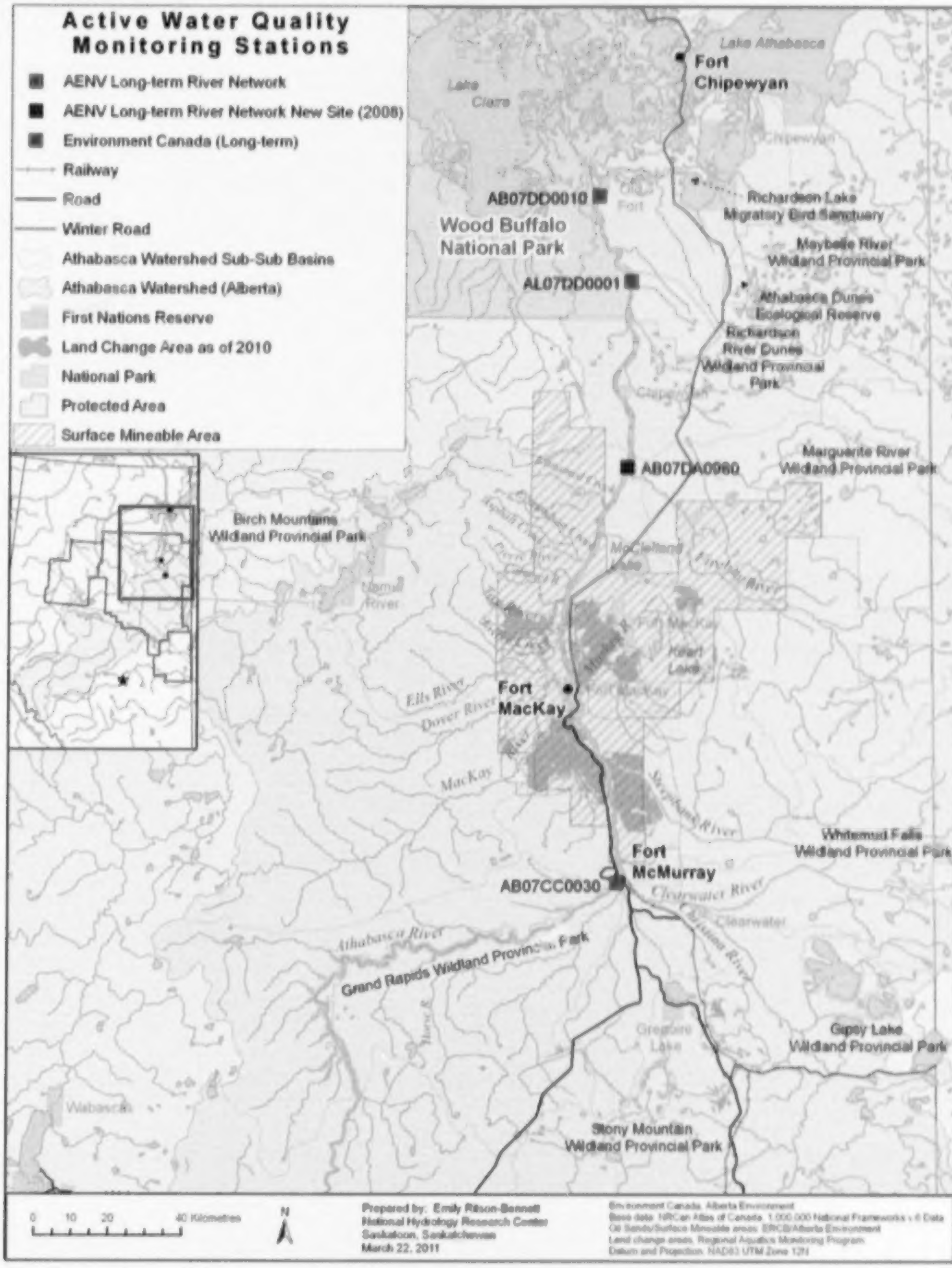


Figure 5: Long term Alberta Environment water quality monitoring stations in the mineable oil sands area.

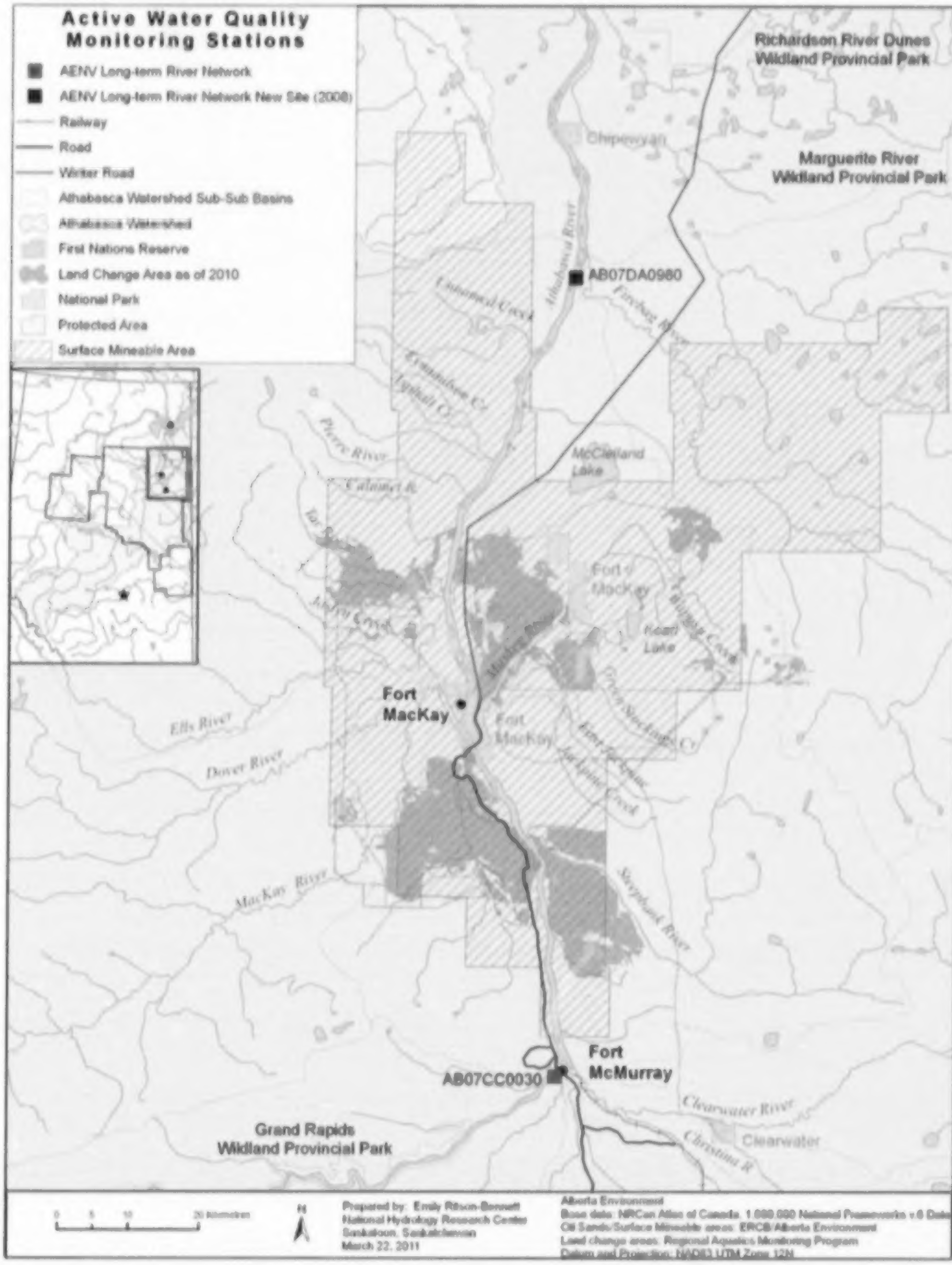


Figure 6: Water Survey of Canada Hydrometric stations, Environment Canada and Alberta Environment climate stations, and Alberta Environment snowpack measurement stations in the Athabasca Basin, Alberta.

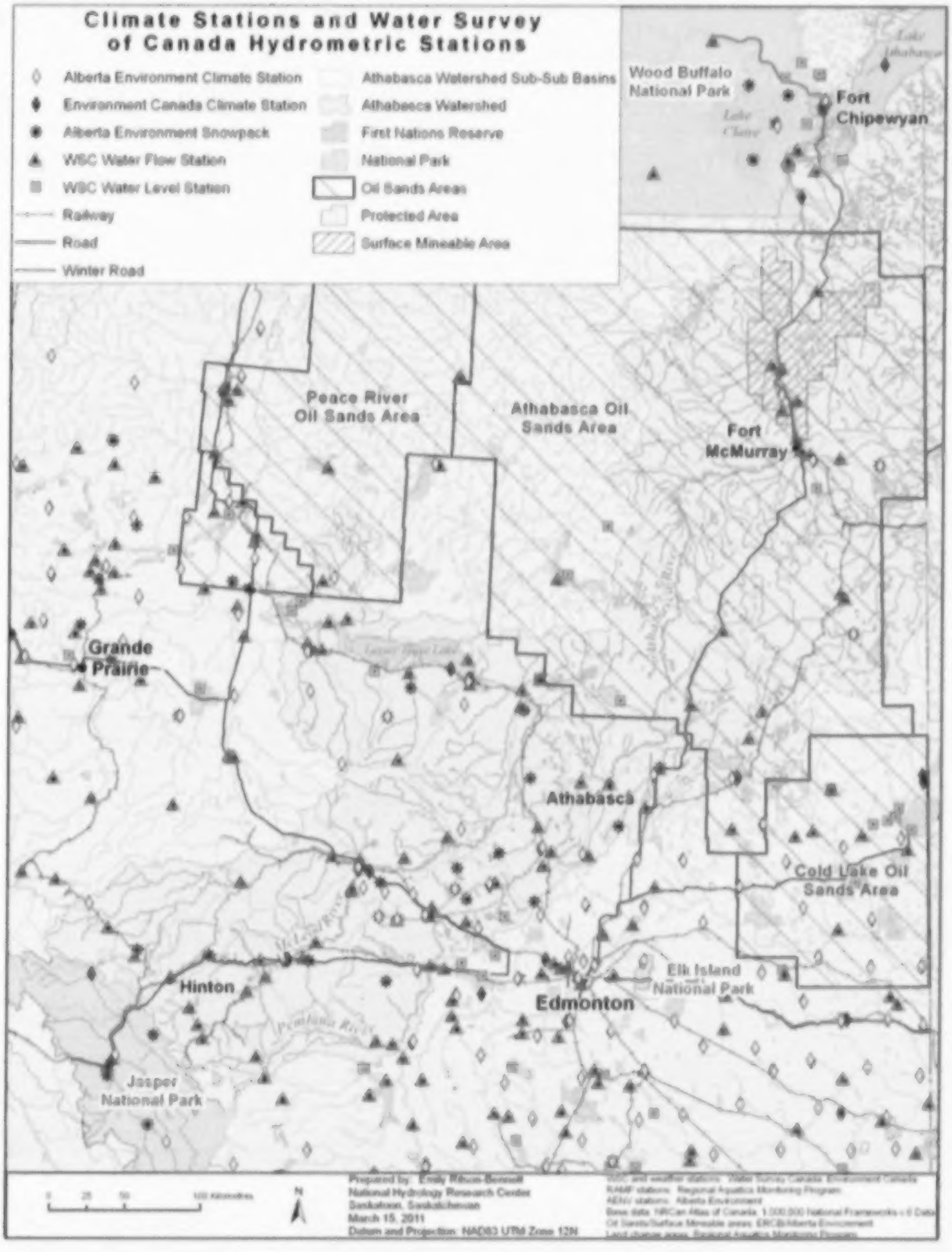


Figure 7: Water Survey of Canada hydrometric stations, Environment Canada and Alberta Environment climate stations, and Alberta Environment snowpack measurement stations in the Lower Athabasca area. AWOS = Automated Weather Observing System, CS = Climate Station, A = Airport (If A is after AWOS, the AWOS is at an airport).

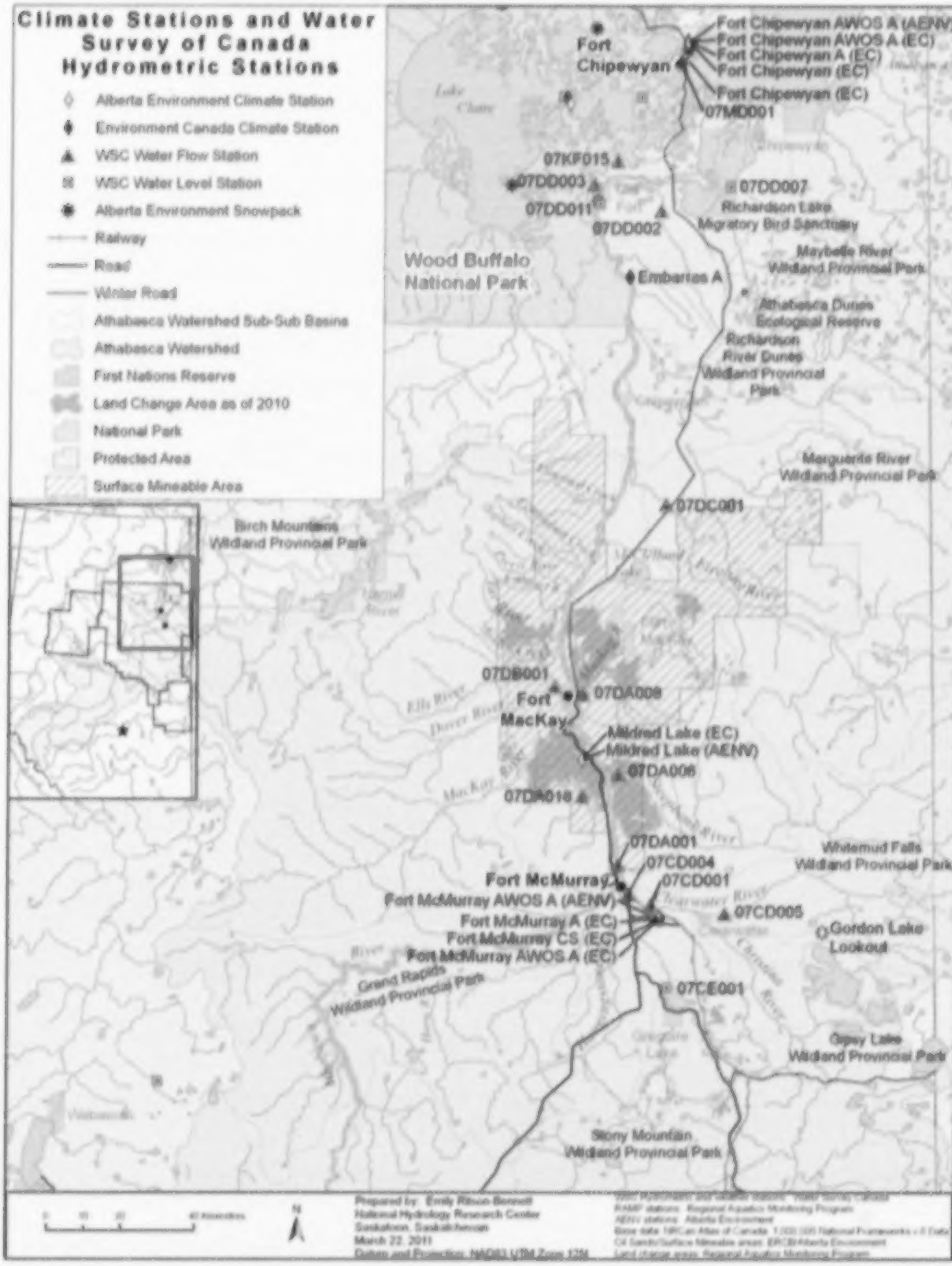


Figure 8: Water Survey of Canada hydrometric stations, Environment Canada and Alberta Environment climate stations, and Alberta Environment snowpack measurement stations in the mineable oilsands area. AWOS = Automated Weather Observing System, CS = Climate Station, A = Airport (If A is after AWOS, the AWOS is at an airport).

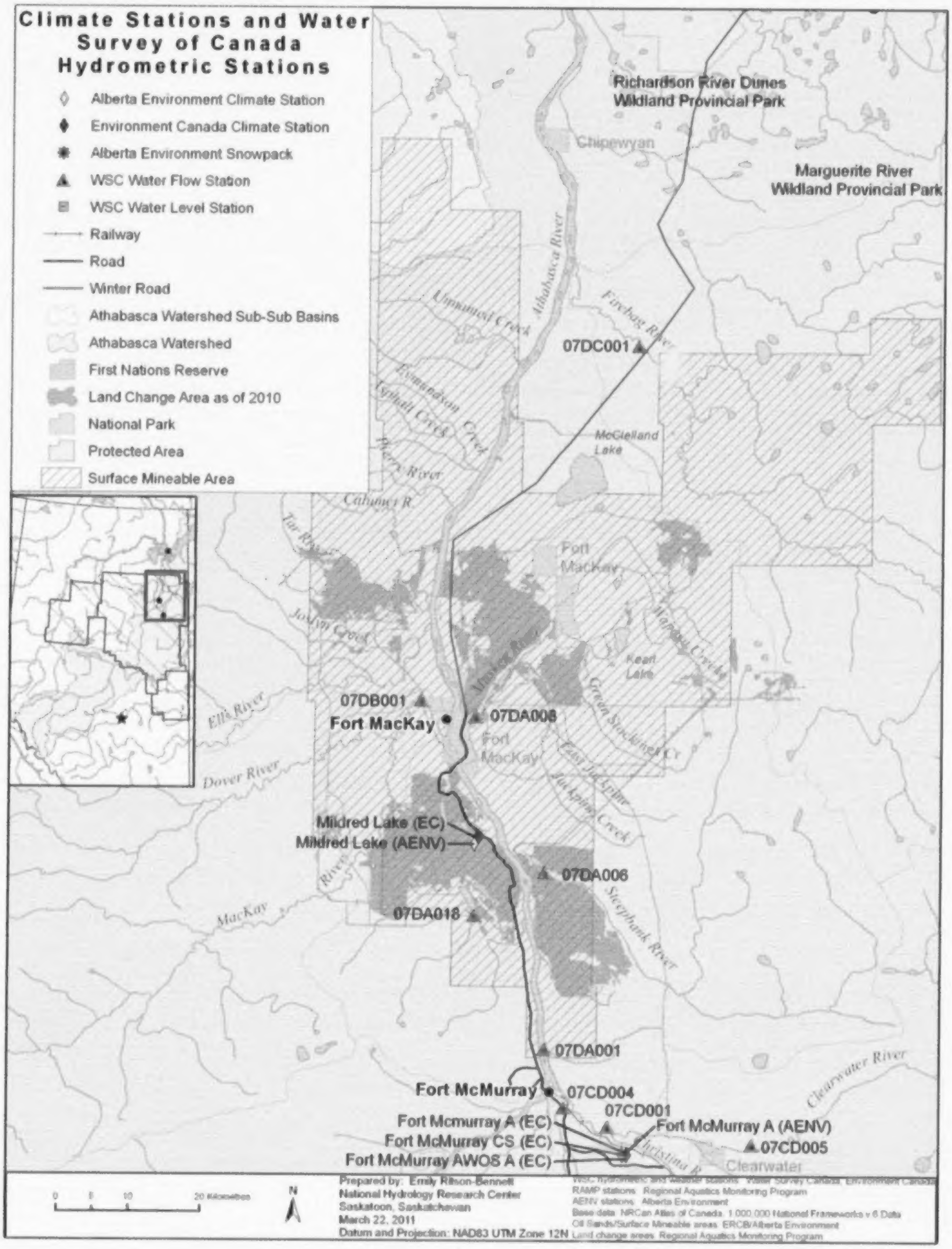


Figure 9: Water Survey of Canada hydrometric stations where data has been collected historically (left), and the current active network (right).

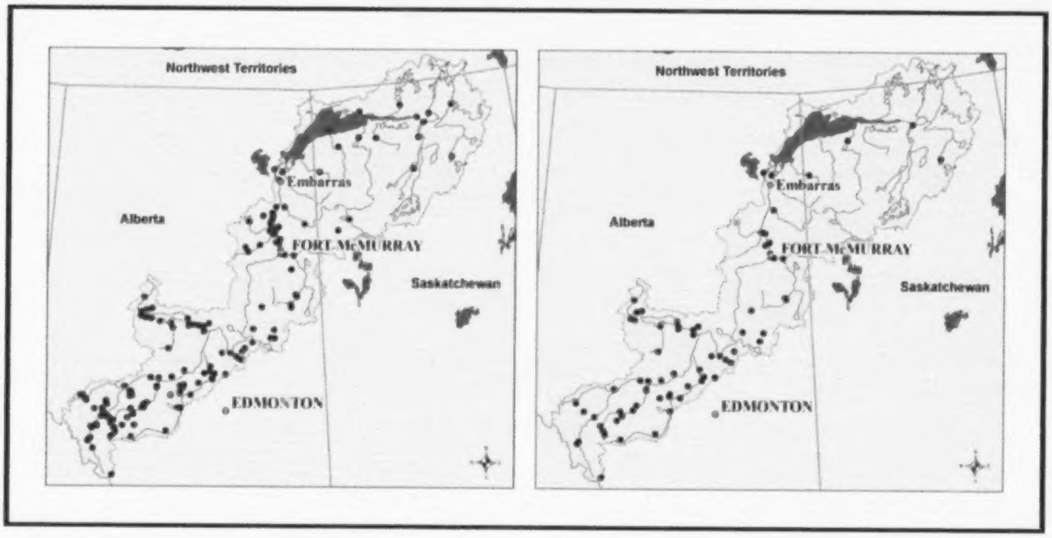


Figure 10: RAMP water quality monitoring sites in the surface-mineable oil sands area. RAMP also has a site near Old Fort, at the Athabasca Delta, and upstream sites on the Christina and Horse Rivers (not shown in this view).

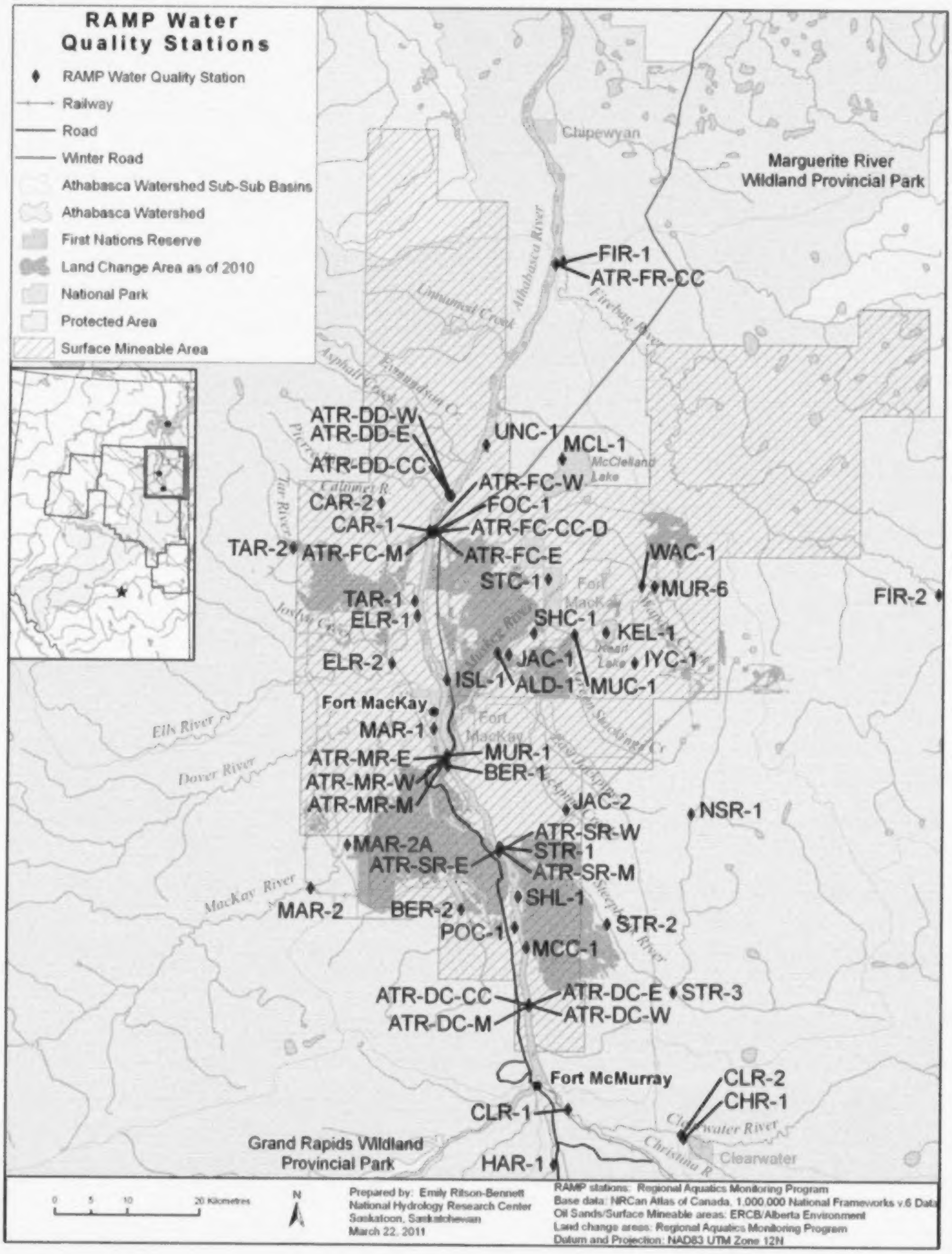


Figure 11: RAMP water quantity, snowpack measurement and climate monitoring sites in the mineable oil sands area. A hydrometric site operated by Canadian Natural Resources Ltd. is also shown for completeness.

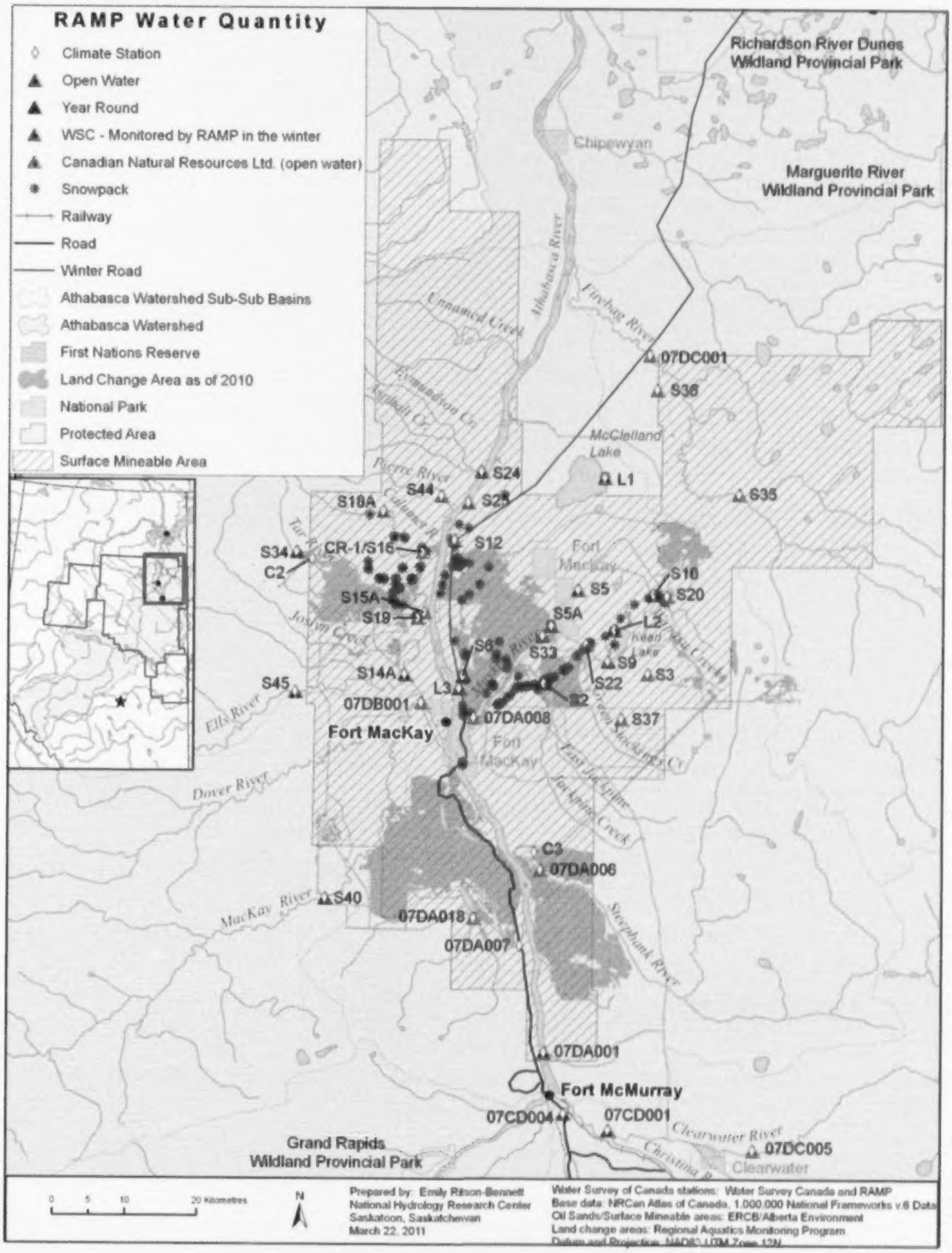


Figure 12: RAMP sediment sampling stations in the Lower Athabasca.

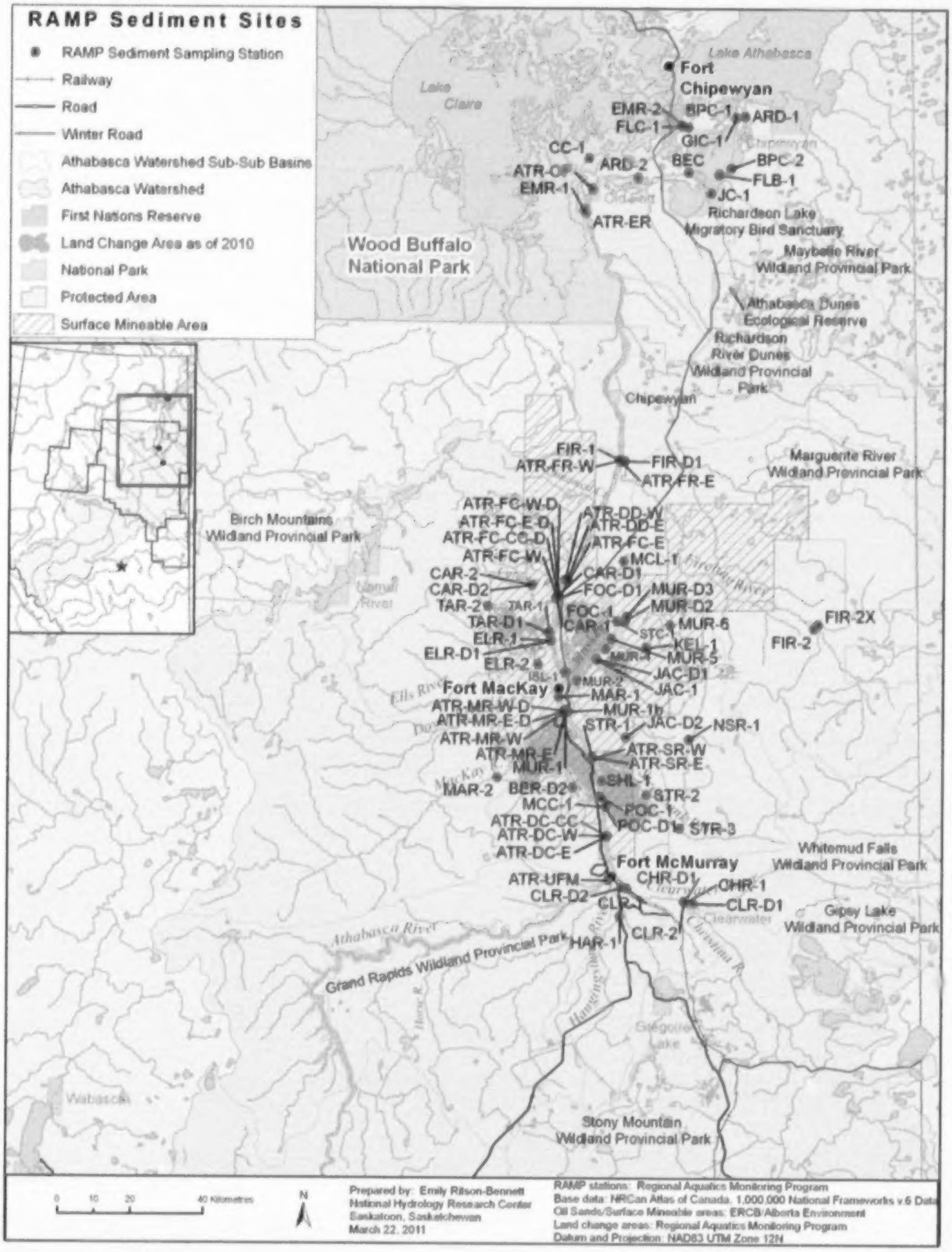


Figure 13: RAMP sediment sampling stations in the surface-mineable oil sands area.

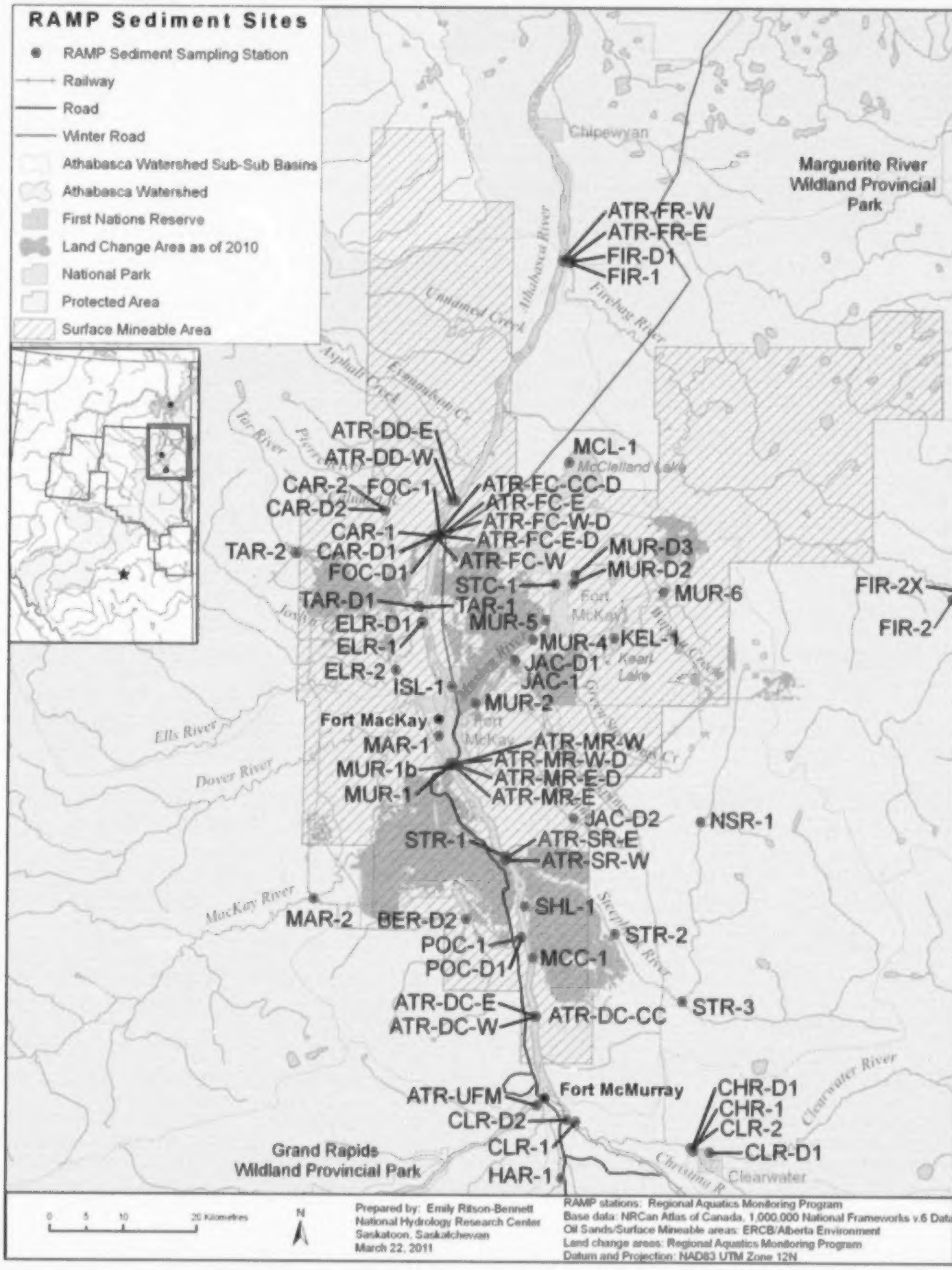


Figure 14: The Alberta Environment Comprehensive Contaminant Loading Study and the Muskeg River Water Management Framework sampling sites (provincial focussed studies). Note that site 6 at Old Fort is downstream of the extent of this map.

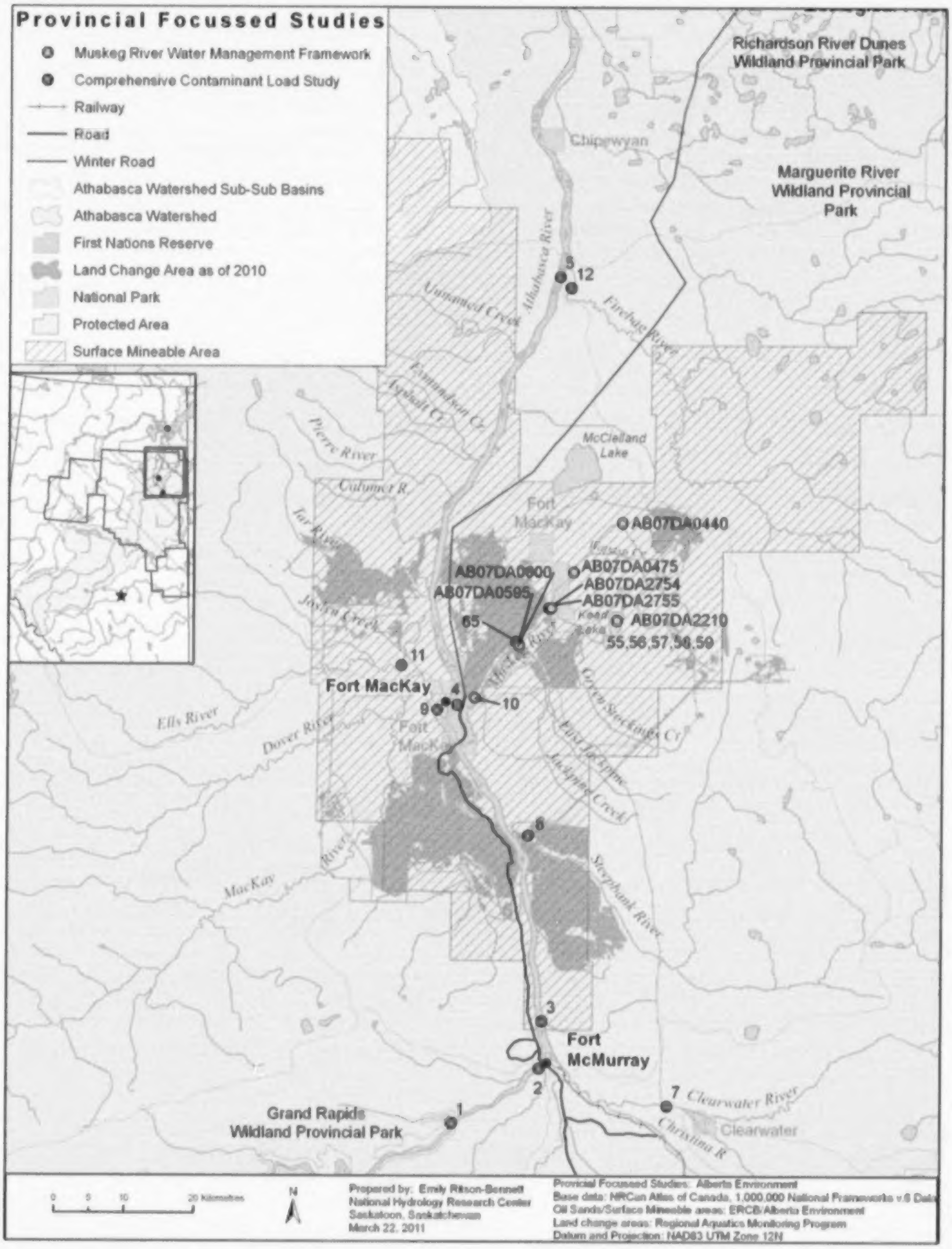


Figure 15: Environment Canada focussed surface water/groundwater interaction study, perched groundwater seeps and the University of Calgary/NRCan deep Palaeozoic study locations.

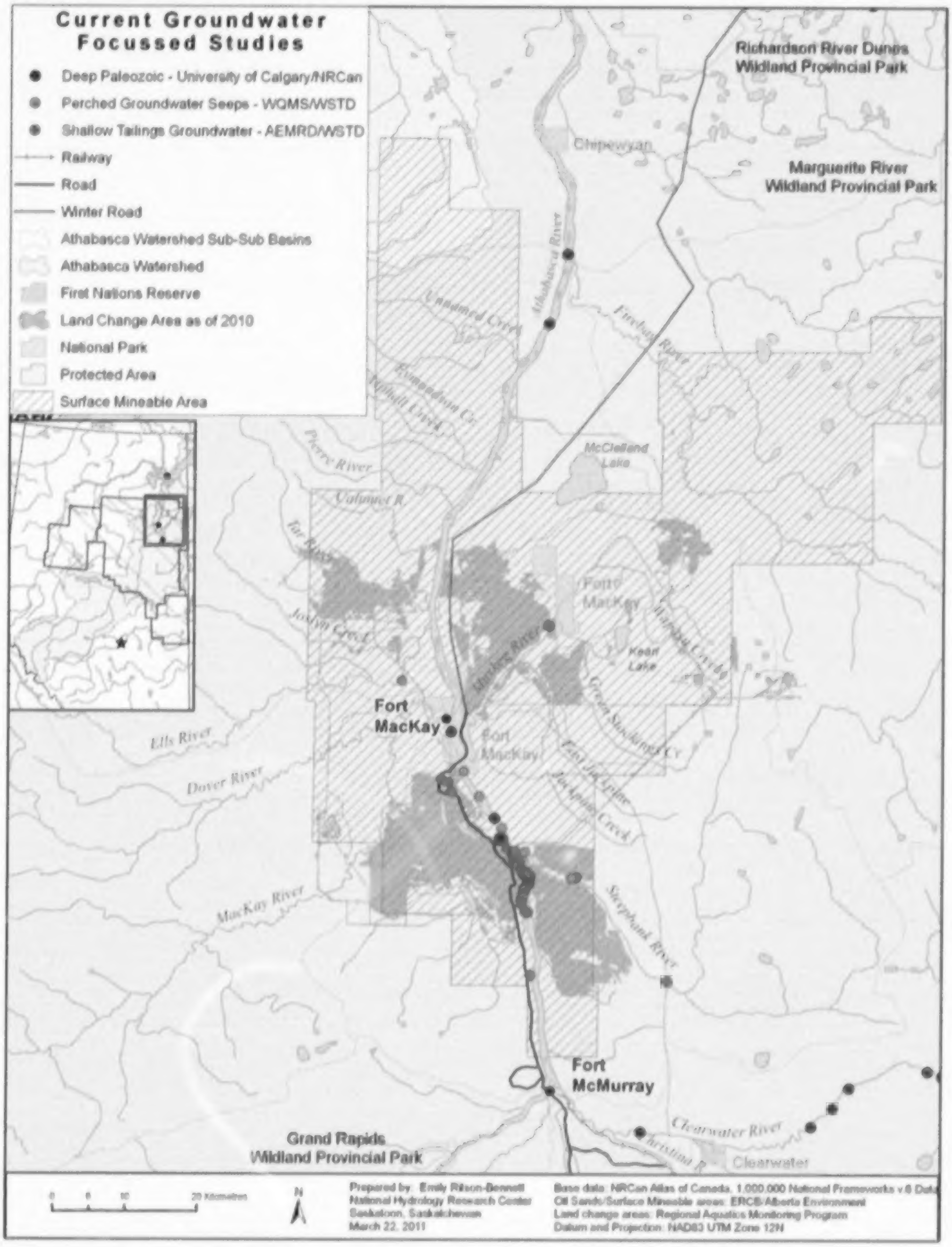


Figure 16: Kelly *et al.* (2009, 2010) and three aerial deposition study sites in the Lower Athabasca. The Kelly *et al.* studies are about both atmospheric deposition and waterborne-sources (related to land-clearing).

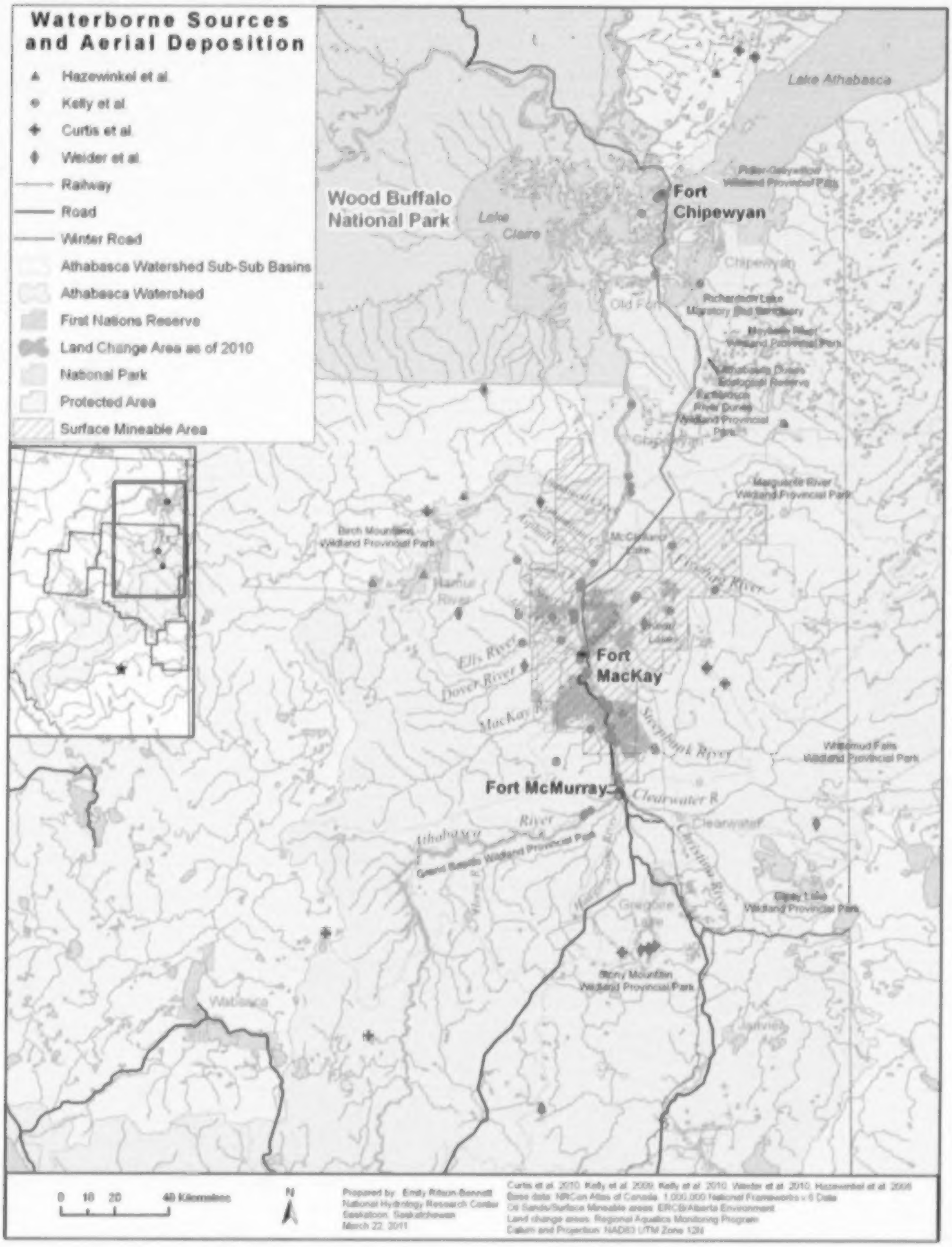


Figure 17: AOSERP water and sediment quality studies in the surface-mineable oil sands area.

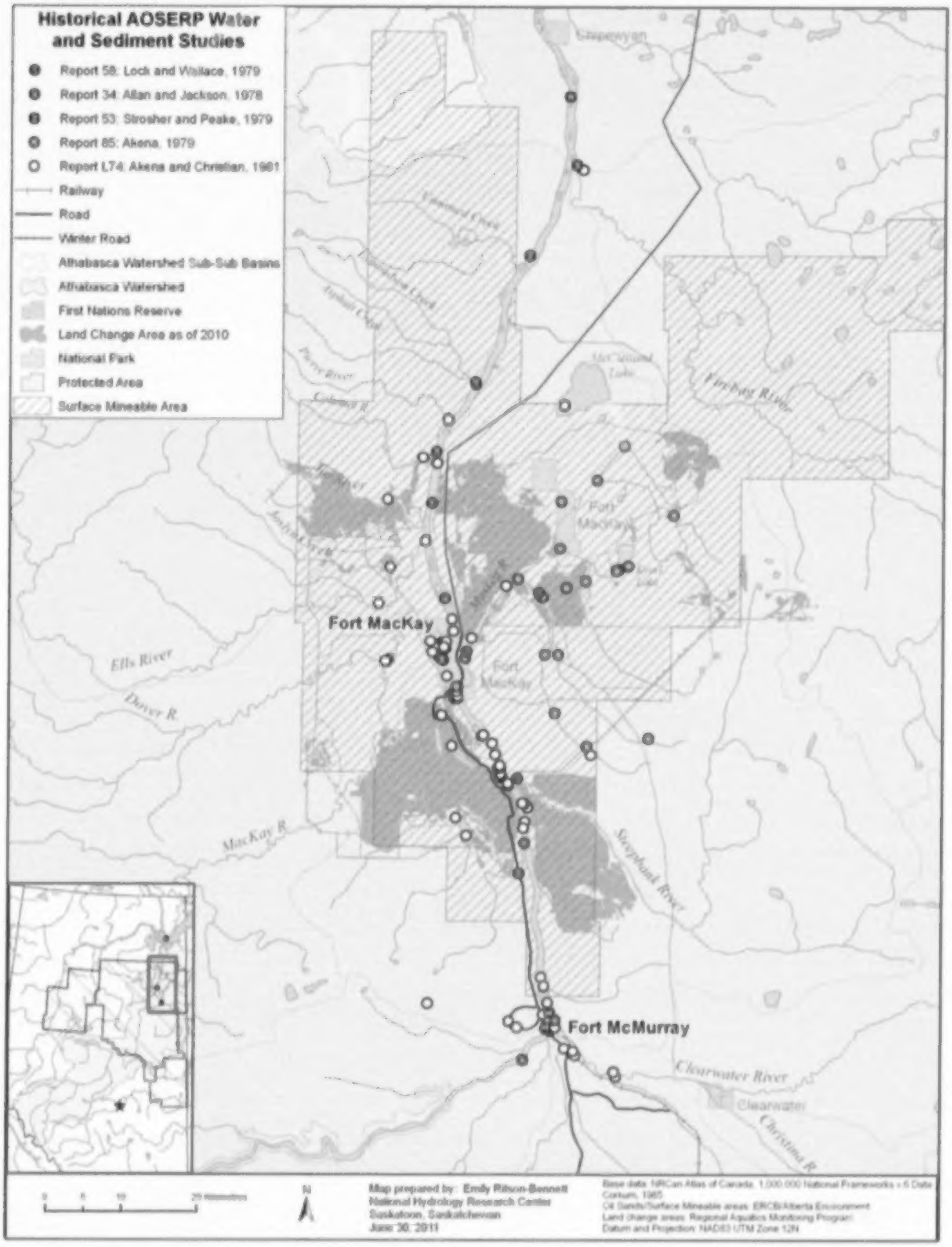


Figure 18: An NREI (PERD-funded) focussed historical study (Headley *et al.*, 2001), and a later follow-up study (Conly *et al.*, 2007) in the Athabasca oil sands area.

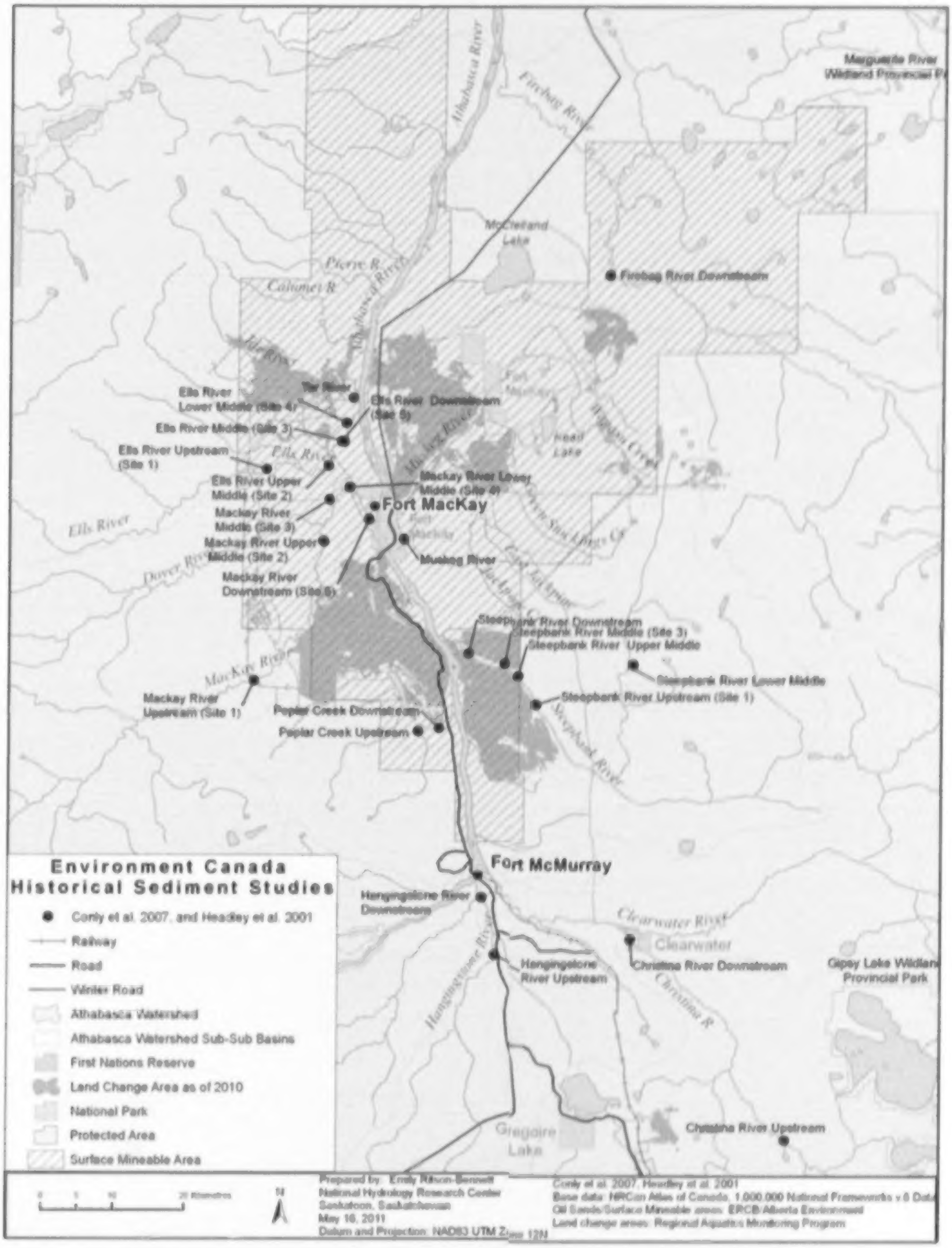


Figure 19: Relative contribution of upper, middle and lower reaches of the Athabasca River to the overall flow.

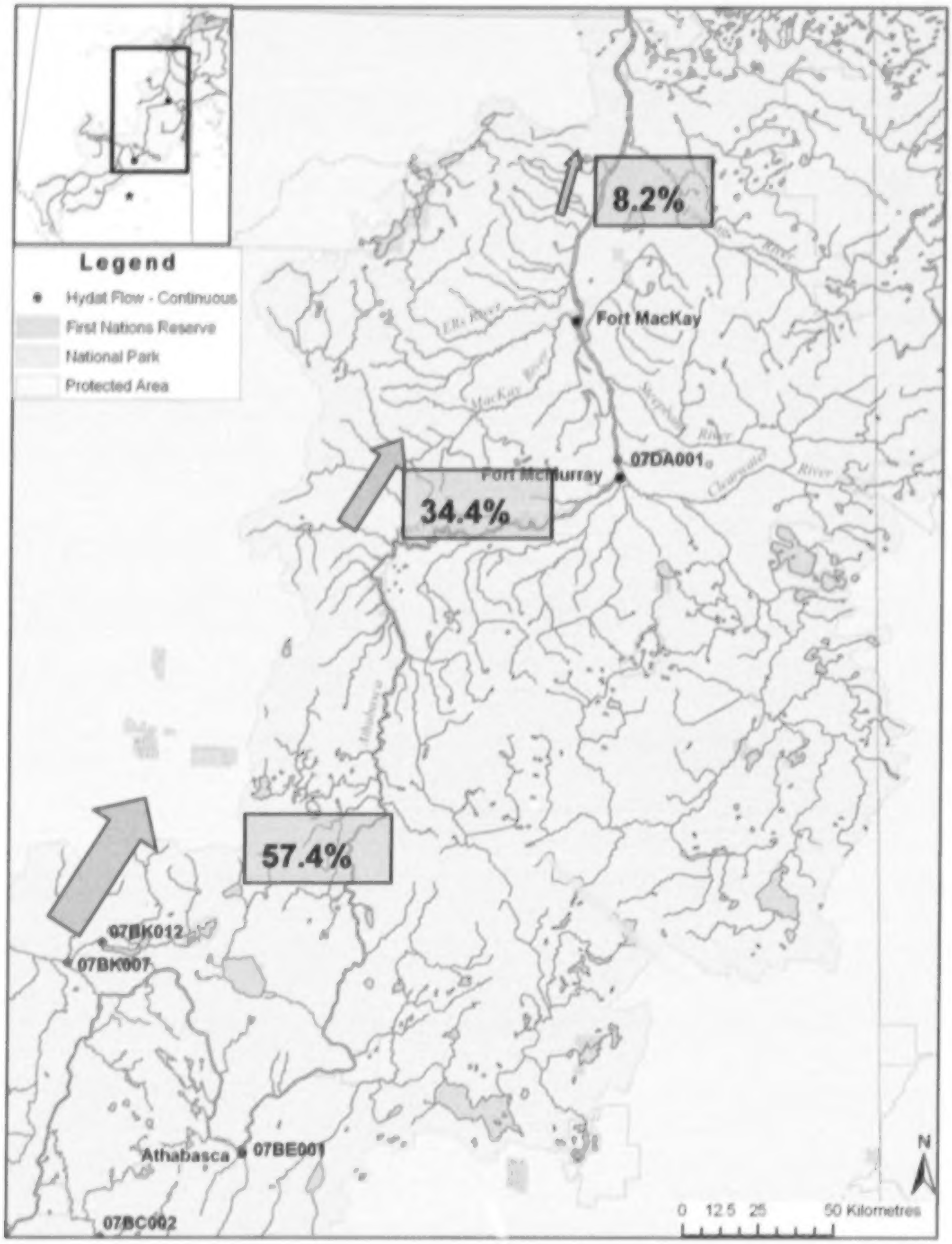


Figure 20: Embarras and Fort McMurray sites - comparison of near coincident direct discharge measurements 1971 through 1980.

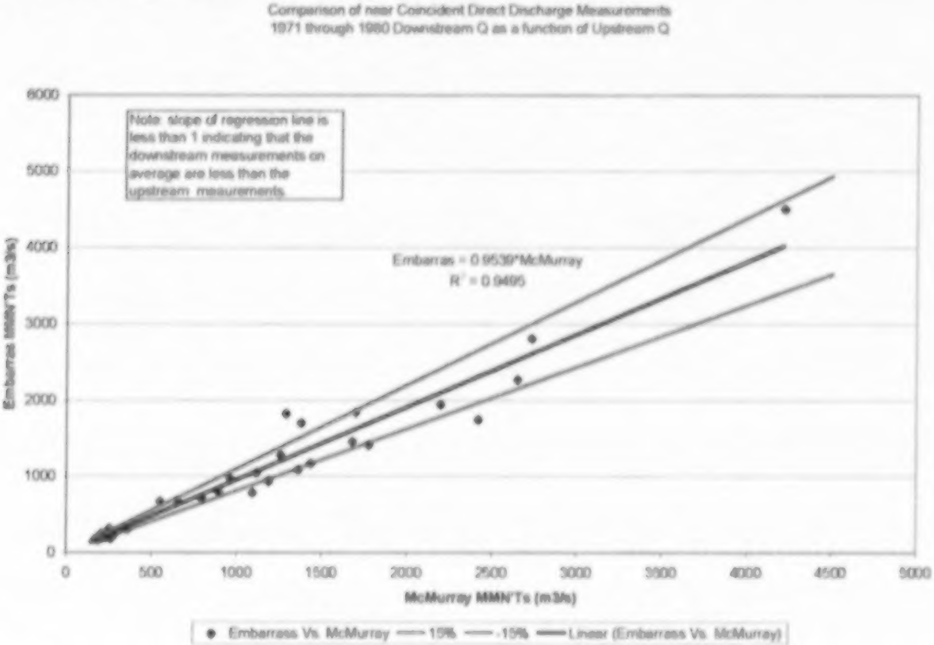


Figure 21: Hydrograph comparison between Fort McMurray and Embarras sites.

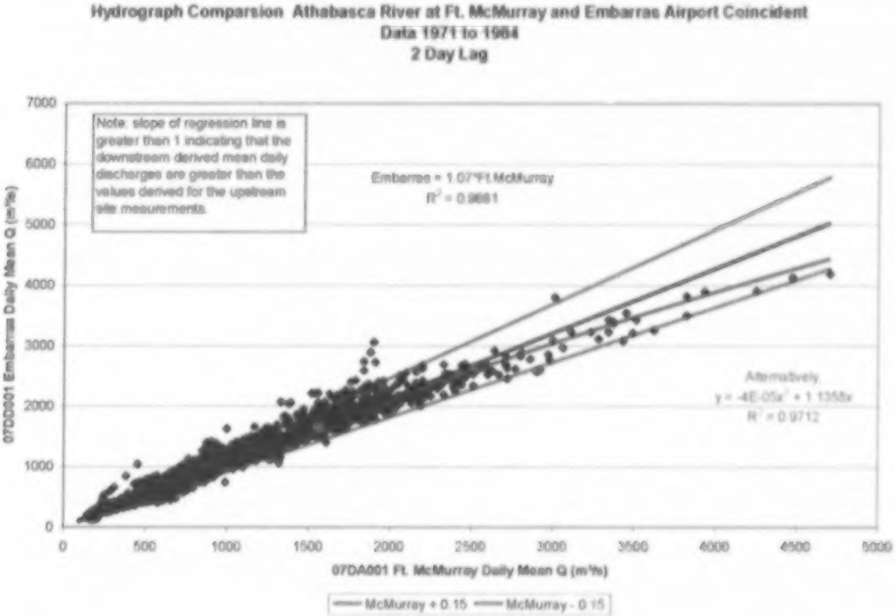


Figure 22: Pulp and paper Environmental Effects Monitoring program water quality sampling sites for mills on the Athabasca mainstem. Mills shown are Hinton Pulp, at Hinton, Alberta Newsprint Company and Millar Western Pulp Ltd. at Whitecourt, and Alberta-Pacific Forest Industries Inc. at Athabasca.

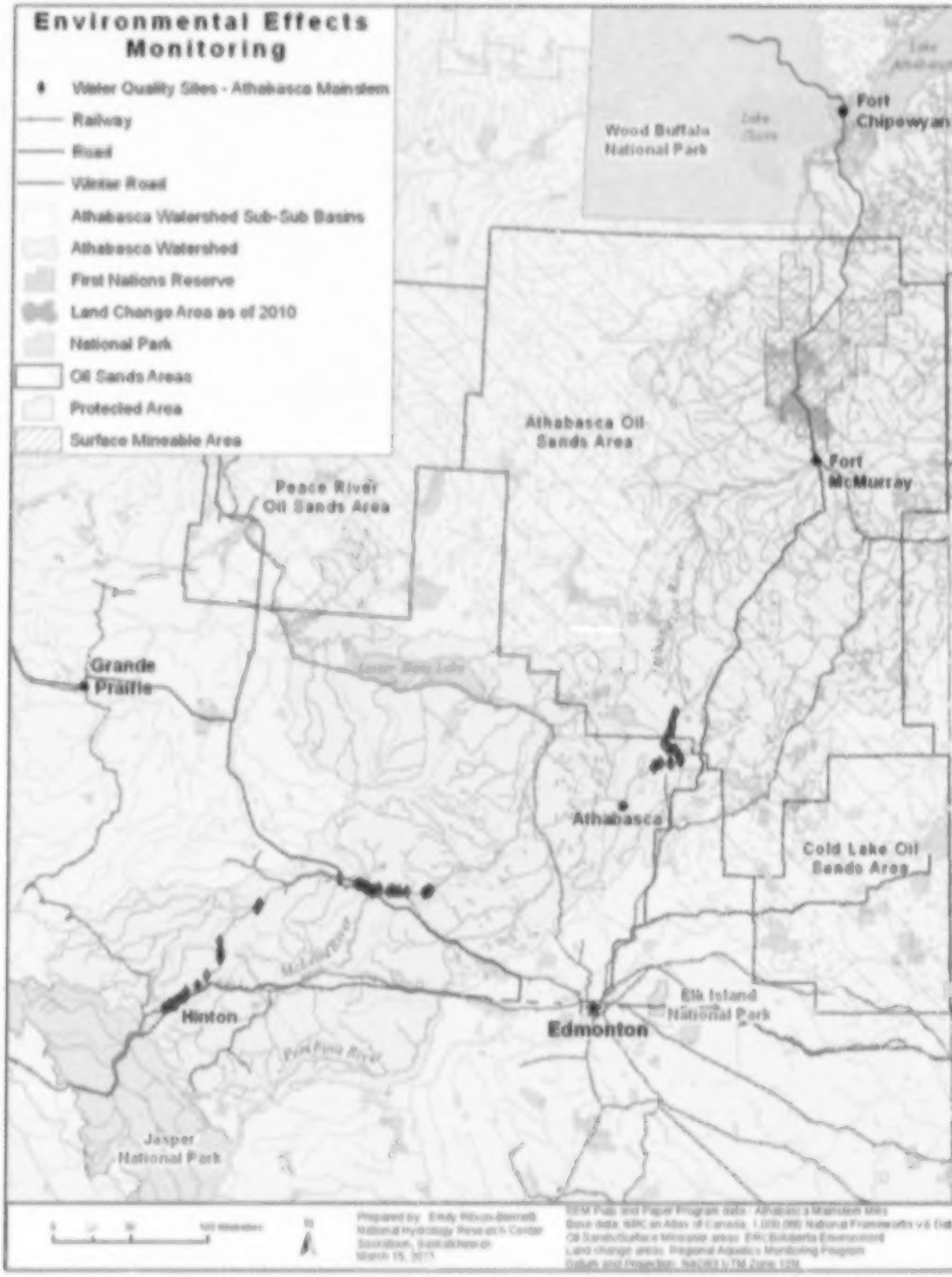
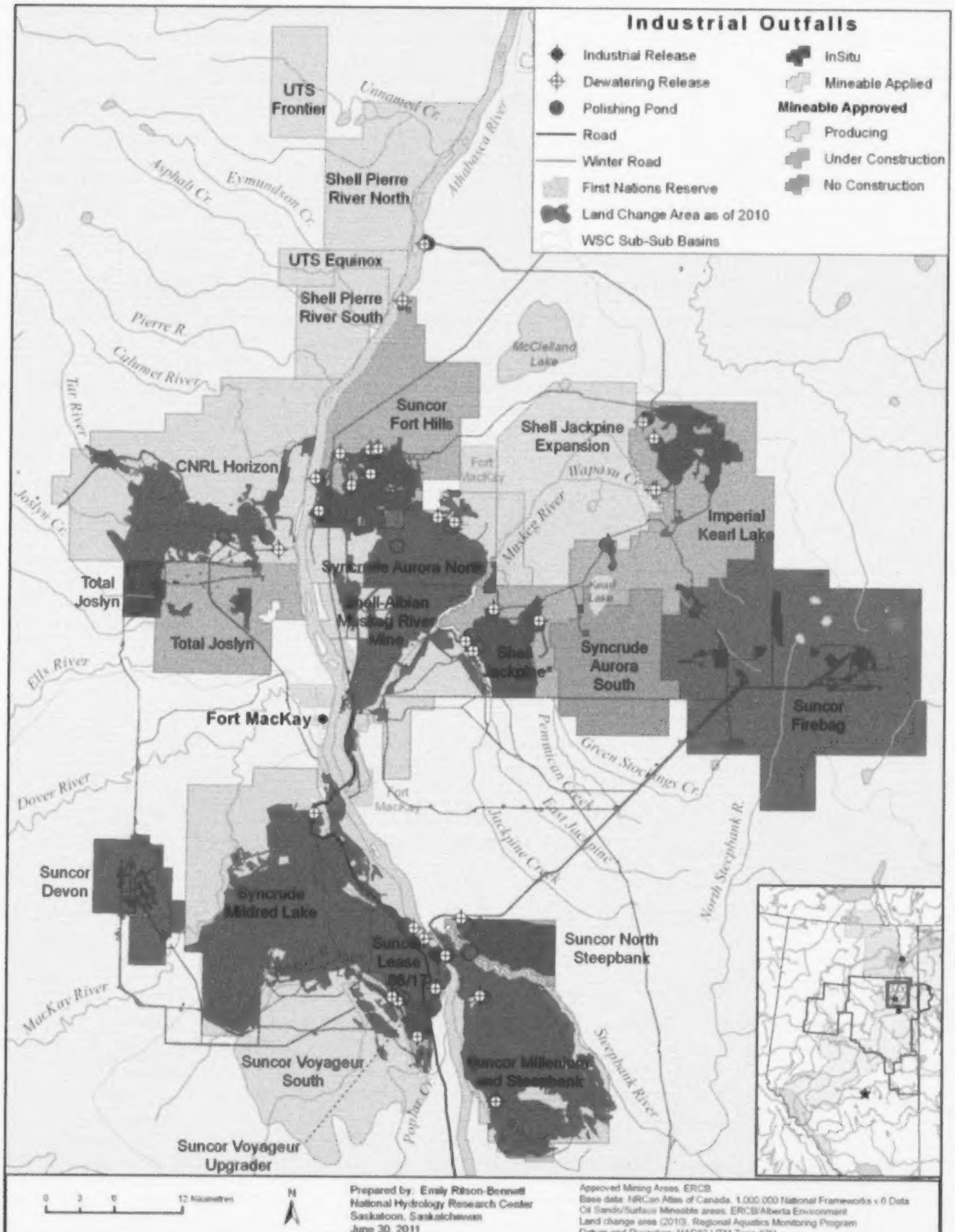


Figure 23: Map of releases (dewatering waters) for oil sands operations ("Mineable Approved"), and the Suncor industrial effluent. "Pond" indicates sedimentation or polishing ponds (not tailings ponds). Planned operations (Mineable Applied) are also shown, for reference.



APPENDIX 1: PARAMETERS SAMPLED, BY MONITORING PROGRAMS AND FOCUSSED STUDIES

The following table includes specific information on parameters sampled by the major monitoring programs and other activities in the oil sands region, up to 2011. Symbols in the cells for each parameter indicate that parameter is sampled for that program or study. AOSERP, NRBS and NREI are identified by study number, so that the number(s) in a cell for a given parameter indicate the study number of a study which sampled that parameter. Cross-references for the study numbers are given below. Notes on parameter suites specific to one study or program only are also given below the table.

Editors' note: IMPORTANT! Appendix 1 contents are historical information from **prior to** the Integrated Monitoring Plan for the Oil Sands, and the Joint Canada | Alberta Implementation Plan for Oil Sands Monitoring. Alberta Environment and Environment Canada parameter lists, sampling sites and frequencies will have differences that will take effect as the Implementation Plan proceeds.

Decision Standards for Inclusion/Exclusion of Documents in the Phase 1/Component 2 Information Table:

NOT INCLUDED:

- Water/sediment quality-related documents that report sampling within the area of interest, but only for contaminants typically associated with pulp and paper mill effluent;
- Documents that discuss sampling programs within the area of interest but exclusively present data from previous studies/reports/programs (i.e., do not report new data);
- One-off hydrological measurements (e.g., flow, depth) taken during water/sediment quality and/or fish/benthic focused studies;
- Databases;
- Documents that collect samples for contaminant analysis which are intended to be presented in subsequent (unreferenced) reports.

INCLUDED:

- Documents that may present only 1 or 2 sampling locations within the area of interest (among a majority of externally located sites);

Contractions used in the table:

AENV – LTRN: Alberta Environment Long Term River Network (see Figures 1-3).

EC: Environment Canada sites on the Athabasca River (see Figures 1-3).

Environmental Effects Monitoring, refers to the EC/AENV EEM program described in section 2 D1 (see Figure 22). EEM water quality data from mills on the Athabasca mainstem were provided by Paula Siwik, EEM coordinator, Prairie and Northern.

RAMP: Regional Aquatics Monitoring Program, described in section 1 A1.3 (see Figures 10, 11, 12 and 13).

CCL: Comprehensive Contaminant Load Study, described in section 1 A2.1.1 (see also Figure 14).

Muskeg River WMF: Muskeg River Water Management Framework, described in section 1 A2.1.2 (see also Figure 14).

Parameters	AENV-LRTN	AENV CCL River	AENV CCL Lakes	AENV Muskeg River WMF	EC Long Term Monitoring	EC Shallow Tailing Groundwater Study	EC Perched Groundwater Study	Environmental Effects Monitoring	RAMP	
More than 5 years of data in program	Yes				Yes			Yes	Yes	Yes
Program/study focus	Water	Water	Water	Water	Water	Water	Watr	Water	Water	Sediment
Reference(s): See table for cross reference	http://environment.alberta.ca/01288.html	Government of Alberta, 2010	Government of Alberta, 2010	Alberta Environment, 2009		Malcolm Conly, pers. comm. 2011	Malcolm Conly, pers. comm. 2011	Paula Siwik, pers. comm. 2011	RAMP 2011, 2009	RAMP 2011, 2009
General frequency of sampling	Monthly	Monthly or 4x/year	Annually	Monthly	Monthly, except 27 Baseline			Once every four years	Note 2 below	Note 3 below
Metals (T - total; D- dissolved; E-extractable)										
Aluminum	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Antimony	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Arsenic	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Barium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Beryllium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Bismuth	TD	TD	TD	TD	TD	D	TD		TD	T
Boron	TD	TD	TD	TD	TD	D	TD	TD	TD	
Cadmium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Chromium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Chromium hexavalent	T	T	TD	T						
Cobalt	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Copper	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Gallium					TD	D	TD			
Iron	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Lanthium					TD	D	TD			
Lead	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Lithium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Manganese	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Mercury	T	T	TD	T			TD	TD	TD	T
Molybdenum	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Nickel	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Rubidium					TD	D	TD			
Selenium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Silver	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Strontium	TD	TD	TD	TD	TD	D	TD		TD	T
Thallium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Thorium	TD	TD	TD	TD					TD	
Tin	TD	TD	TD	TD				TD	TD	T
Titanium	TD	TD	TD	TD				TD	TD	T
Uranium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Vanadium	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Zinc	TD	TD	TD	TD	TD	D	TD	TD	TD	T
Zirconium										
Heavy Metals		T								
PAHs										
1-Methylnaphthalene	x	x		x	x		x			
3-Methylchloranthrene	x	x		x	x		x			
2-Methylnaphthalene	x	x		x	x		x			
7,12-Dimethylbenz(a)anthracene	x	x		x	x		x			
Benzo(c)phenanthrene	x	x		x	x		x			
Naphthalene	x	x		x	x		x		x	x
Acenaphthylene	x	x		x	x		x		x	x

Parameters	AENV-LRTN	AENV CCL River	AENV CCL Lakes	AENV Muskeg River WMF	EC Long Term Monitoring	EC Shallow Tailing Groundwater Study	EC Perched Groundwater Study	Environmental Effects Monitoring	RAMP	
More than 5 years of data in program	Yes				Yes			Yes	Yes	Yes
Program/study focus	Water	Water	Water	Water	Water	Water	Watr	Water	Water	Sediment
Reference(s): See table for cross reference	http://environment.alberta.ca/01288.html	Government of Alberta, 2010	Government of Alberta, 2010	Alberta Environment, 2009		Malcolm Conly, pers. comm. 2011	Malcolm Conly, pers. comm. 2011	Paula Siwik, pers. comm. 2011	RAMP 2011, 2009	RAMP 2011, 2009
General frequency of sampling	Monthly	Monthly or 4x/year	Annually	Monthly	Monthly, except 27 Baseline			Once every four years	Note 2 below	Note 3 below
Acenaphthene	x	x		x	x		x		x	x
Fluorene	x	x		x	x		x		x	x
Phenanthrene	x	x		x	x		x		x	x
Anthracene	x	x		x	x		x		x	x
Fluoranthene	x	x		x	x		x		x	x
Pyrene	x	x		x	x		x		x	x
Benz[a]anthracene	x	x		x	x		x		x	x
Chrysene	x	x		x	x		x		x	x
Benzo[b]fluoranthene	x	x		x	x		x		x	x
Benzo[j,k]fluoranthene	x	x		x	x		x		x	x
Benzo[e]pyrene	x	x		x	x		x			
Benzo[a]pyrene	x	x		x	x		x		x	x
Dibenzo[AH]pyrene	x	x		x	x		x			
Dibenzo[AI]pyrene	x	x		x	x		x			
Dibenzo[AL]pyrene	x	x		x	x		x			
Perylene	x	x		x	x		x			
Dibenzo[a,h]anthracene	x	x		x	x		x		x	x
Indeno[1,2,3-c,d]-pyrene	x	x		x	x		x		x	x
Benzo[g,h,i]perylene	x	x		x	x		x		x	x
Acridine		x		x	x		x			
Methyl Acenaphthene		x							x	x
Biphenyl		x							x	x
Retene	x	x		x	x		x		x	x
Dibenzopthiophene		x							x	x
Methyl-Biphenyl		x							x	x
Dimethyl-Biphenyl		x							x	x
C1-Benzofluoranthene/ Benzopyrenes		x							x	x
C2-Benzofluoranthene/ Benzopyrenes		x							x	x
C1-Naphthalenes		x							x	x
C2-Naphthalenes		x							x	x
C3-Naphthalenes		x							x	x
C4-Naphthalenes		x							x	x
C1-Fluorenes		x							x	x
C2-Fluorenes		x							x	x
C3-Fluorenes		x								x
C4-Fluorenes										
C1-Dibenzopthiophene		x							x	x
C2-Dibenzopthiophenes		x							x	x
C3-Dibenzopthiophenes		x							x	x
C4-Dibenzopthiophenes		x							x	x
C1-Phenanthrenes/ Anthracenes		x							x	x
C2-Phenanthrenes/ Anthracenes		x							x	x

Parameters	AENV-LRTN	AENV CCL River	AENV CCL Lakes	AENV Muskeg River WMF	EC Long Term Monitoring	EC Shallow Tailing Groundwater Study	EC Perched Groundwater Study	Environmental Effects Monitoring	RAMP	
More than 5 years of data in program	Yes				Yes			Yes	Yes	Yes
Program/study focus	Water	Water	Water	Water	Water	Water	Watr	Water	Water	Sediment
Reference(s): See table below for cross reference	http://environment.alberta.ca/01288.html	Government of Alberta, 2010	Government of Alberta, 2010	Alberta Environment, 2009		Malcolm Conly, pers. comm. 2011	Malcolm Conly, pers. comm. 2011	Paula Siwik, pers. comm. 2011	RAMP 2011, 2009	RAMP 2011, 2009
General frequency of sampling	Monthly	Monthly or 4x/year	Annually	Monthly	Monthly, except 27 Baseline			Once every four years	Note 2 below	Note 3 below
C3-Phenanthrenes/ Anthracenes		x							x	x
C4-Phenanthrenes/ Anthracenes		x							x	x
C1-Fluoranthenes/Pyrenes		x							x	x
C2-Fluoranthenes/Pyrenes										x
C3-Fluoranthenes/Pyrenes										x
C4-Fluoranthenes/Pyrenes										
C1-Benz[a]anthracenes/ Chrysenes		x							x	x
C2-Benz[a]anthracenes/ Chrysenes	x	x							x	x
C1-Chrysene										
C2-Chrysene										
C3-Chrysene										
C4-Chrysene										
Naphthenic Acids										
total	x	x		x	x	x	x		x	
Nutrients										
DOC	x	x	x	x	x			x	x	
DIC			x					x	x	
TOC	x	x		x	x			x	x	x
POC								x		
DKN								x		
TKN	x	x	x	x	x			x	x	
DON								x		
PON										
TDN			x		x			x	x	
TN	x	x	x	x	x			x	x	
TIN										
NH_4						x				
Ammonia-N	x	x	x	x	x			x	x	
Nitrate + nitrite	x	x	x	x	x	x		x	x	
Chlorophyll a	x	x	x	x	x			x	x	
TP	x	x	x	x	x			x	x	x
TDP	x	x	x	x	x			x	x	
Reactive Silica	x	x		x	x			x		
Major Ions										
Calcium	x	x	x	x	x			x	x	x
Potasium	x	x	x	x	x			x	x	x
Magnesium	x	x	x	x	x			x	x	x
Sodium	x	x	x	x	x			x	x	x
Sulphide	x	x		x	x			x	x	
Sulphate	x	x	x	x	x	x		x	x	
Chloride	x	x	x	x	x			x	x	
Fluoride										

Parameters	**AENV-LRTN**	**AENV CCL River**	**AENV CCL Lakes**	**AENV Muskeg River WMF**	**EC Long Term Monitoring**	**EC Shallow Tailing Groundwater Study**	**EC Perched Groundwater Study**	**Environmental Effects Monitoring**	**RAMP**	
More than 5 years of data in program	Yes				Yes			Yes	Yes	Yes
Program/study focus	Water	Water	Water	Water	Water	Water	Watr	Water	Water	Sediment
Reference(s): See table below for cross reference	http://environment.alberta.ca/01288.html	Government of Alberta, 2010	Government of Alberta, 2010	Alberta Environment, 2009		Malcolm Conly, pers. comm. 2011	Malcolm Conly, pers. comm. 2011	Paula Siwik, pers. comm. 2011	RAMP 2011, 2009	RAMP 2011, 2009
General frequency of sampling	Monthly	Monthly or 4x/year	Annually	Monthly	Monthly, except 27 Baseline			Once every four years	Note 2 below	Note 3 below
Silicon			x					x	x	
Hardness	x	x	x	x	x			x	x	
Alkalinity	x	x	x	x	x	x			x	
Bicarbonate	x	x	x	x	x			x	x	
Physicals										
Conductivity/ conductance	x	x	x	x	x		x		x	
pH	x	x	x	x	x	x	x	x	x	
Temperature	x	x		x	x		x	x		
Turbidity	x	x	x	x	x			x	x	
TDS	x	x	x	x	x			x	x	
TSS	x	x	x	x	x			x	x	
BOD	x	x		x	x			x	x	
Colour	x	x	x	x	x			x	x	
Petroleum Hydrocarbons										
Benzene	x	x		x	x	x				x
Toluene	x	x		x	x	x				x
Ethylene	x	x		x	x	x				x
Xylene	x	x		x	x	x				x
F1 (C6-C10)		x		x	x					x
F2 (C10-C16)		x		x	x					x
F3 (C16-C34)		x		x	x					x
F4 (C34-C50)		x		x	x					x
Oil and Grease										
colourimetric										
gravimetric										
Cyanide	x	x		x	x					
Organics, including pesticides (see list of parameters below table)	Note 1									

Note
[Bold = SPMDs only]

Note 2
Seasonal sampling during first 3 years at a new site, then once per year in Fall with limited seasonal sampling for various sites
Prior to 2006 = Annual Fall

Note 3
sampling during first 3 years, thereafter once every 3 years for sites located in watersheds bearing pre-existing RAMP stations; 2006-present = sampled in conjunction with benthic invertebrate schedule

Parameters	AOSERP			NRBS		Syncrude 1977	Syncrude 1978; 1977	Kelly *et al.*, 2010; 2009	Hazewinkel *et al.*, 2008; Curtis *et al.*, 2010	Colavecchia *et al.*, 2004	Conly *et al.*, 2007; Headley *et al.*, 2001
More than 5 years of data in program											
Program/study focus	Water & Sediment	Water	Sediment	Sediment		Water	Water	Water	Water	Sediment	Sediment
Reference(s): See table below for cross reference	17 / 53	71 / 85 / 87/ 94 / L-74	34	Crosley 1996	Brownlee *et al.* 1996	Aquatic Environments Ltd. 1977	Aquatic Environments Ltd. 1978; 1977				
General frequency of sampling											Annually for 3 years
Metals (T - total; D- dissolved; E-extractable)											
Aluminum		85[T]	34				x				
Antimony								TD			
Arsenic	17	85[T]	34					TD			T
Barium			34								
Beryllium			34					TD			
Bismuth		85[T]									
Boron		85[T]					x				
Cadmium	17	85[T], L-74[E]					x	TD			T
Chromium	17	L-74[E]	34				x	TD			
Chromium hexavalent		85[T]									
Cobalt		85[T], L-74[E]	34				x				T
Copper	17	85[T], L-74[E]	34				x	TD			T
Gallium											
Iron	17	71, 85[T], 87, 94[T], L-74[E]	34				x				T
Lanthium											
Lead	17	85[T], L-74[E]	34				x	TD			T
Lithium											
Manganese	17	71, 85[T], L-74[E]	34								T
Mercury	17	85[T], L-74[E]	34	x			x	TD			
Molybdenum											
Nickel	17	85[T], L-74[E]	34				x	TD			T
Rubidium											
Selenium	17	85[T]						TD			
Silver		85[T]						TD			
Strontium			34								T
Thallium								TD			
Thorium											
Tin											
Titanium		85[T]	34								
Uranium											
Vanadium	17	85[T]	34				x				
Zinc	17	85[T], L-74[E]	34				x	TD			
Zirconium											
Heavy Metals											
PAHs	53										
1-Methylnaphthalene											
3-Methylchloranthrene											
2-Methylnaphthalene											
7,12-Dimethylbenz(a)anthracene											
Benzo(c)phenanthrene											
Naphthalene				x				x		x	x
Acenaphthylene				x				x		x	x

Parameters	AOSERP			NRBS		Syncrude 1977	Syncrude 1978; 1977	Kelly *et al.*, 2010; 2009	Hazewinkel *et al.*, 2008; Curtis *et al.*, 2010	Colavecchia *et al.*, 2004	Conly *et al.* 2007; Headley *et al.*, 2001
More than 5 years of data in program											
Program/study focus	Water & Sediment	Water	Sediment	Sediment		Water	Water	Water	Water	Sediment	Sediment
Reference(s): See table below for cross reference	17 / 53	71 / 85 / 87/ 94 / L-74	34	Crosley 1996	Brownlee *et al.*, 1996	Aquatic Environments Ltd. 1977	Aquatic Environments Ltd. 1978; 1977				
General frequency of sampling											Annually for 3 years
Acenaphthene				x				x		x	x
Fluorene				x				x		x	x
Phenanthrene				x	x			x		x	x
Anthracene				x				x		x	x
Fluoranthene				x	x			x		x	x
Pyrene				x	x			x		x	x
Benz[a]anthracene				x	x			x		x	x
Chrysene				x	x			x		x	x
Benzo[b]fluoranthene				x	x			x		x	x
Benzo[j,k]fluoranthene				x				x		x	x
Benzo[e]pyrene				x						x	x
Benzo[a]pyrene				x	x			x		x	x
Dibenzo[AH]pyrene											x
Dibenzo[AI]pyrene											x
Dibenzo[AL]pyrene											x
Perylene				x						x	x
Dibenzo[a,h]anthracene				x	x			x		x	x
Indeno[1,2,3-c,d]-pyrene				x	x			x		x	x
Benzo[g,h,i]perylene				x	x			x		x	x
Acridine											
Methyl Acenaphthene											
Biphenyl								x			x
Retene				x							
Dibenzopthiophene				x				x			x
Methyl-Biphenyl											
Dimethyl-Biphenyl											
C1-Benzofluoranthene/ Benzopyrenes										x	
C2-Benzofluoranthene/ Benzopyrenes										x	
C1-Naphthalenes				x				x		x	x
C2-Naphthalenes				x				x		x	x
C3-Naphthalenes				x				x		x	x
C4-Naphthalenes				x				x		x	x
C1-Fluorenes								x		x	x
C2-Fluorenes								x		x	x
C3-Fluorenes								x		x	x
C4-Fluorenes								x			x
C1-Dibenzopthiophene				x				x			x
C2-Dibenzopthiophenes				x				x			x
C3-Dibenzopthiophenes								x			x
C4-Dibenzopthiophenes								x			x
C1-Phenanthrenes/ Anthracenes								x		x	x
C2-Phenanthrenes/ Anthracenes								x		x	x

Parameters	AOSERP			NRBS		Syncrude 1977	Syncrude 1978; 1977	Kelly *et al.* 2010; 2009	Hazewinkel *et al.* 2008; Curtis *et al.* 2010	Colavecchia *et al.* 2004	Conly *et al.* 2007; Headley *et al.* 2001
More than 5 years of data in program											
Program/study focus	Water & Sediment	Water	Sediment	Sediment		Water	Water	Water	Water	Sediment	Sediment
Reference(s): See table below for cross reference	17 / 53	71 / 85 / 87/ 94 / L-74	34	Crosley 1996	Brownlee *et al.* 1996	Aquatic Environments Ltd. 1977	Aquatic Environments Ltd. 1978; 1977				
General frequency of sampling											Annually for 3 years
C3-Phenanthrenes/ Anthracenes								x		x	x
C4-Phenanthrenes/ Anthracenes								x		x	x
C1-Fluoranthenes/Pyrenes				x				x		x	x
C2-Fluoranthenes/Pyrenes				x				x		x	x
C3-Fluoranthenes/Pyrenes				x				x		x	x
C4-Fluoranthenes/Pyrenes				x				x		x	x
C1-Benz[a]anthracenes/ Chrysenes										x	
C2-Benz[a]anthracenes/ Chrysenes										x	
C1-Chrysene								x			x
C2-Chrysene								x			x
C3-Chrysene								x			x
C4-Chrysene								x			x
Naphthenic Acids											
total											
Nutrients											
DOC											
DIC		71, 85									
TOC		85, 94	34				x				
POC											
DKN											
TKN		85, L-74	34								
DON											
PON											
TDN		71				x					
TN							x		x		
TIN											
NH_4											
Ammonia-N		71, 85, 94									
Nitrate + nitrite		71, 85									
Chlorophyll a		71, 85, L-74									
TP		85, 94					x		x		
TDP		71				x	x				
Reactive Silica		94, L-74				x	x				
Major Ions											
Calcium		71, 85, 87, 94, L-74	34			x	x				
Potasium		71, 85, 87, 94, L-74				x	x				
Magnesium		71, 85, 87, 94, L-74	34			x	x				
Sodium		71, 85, 87, 94, L-74	34			x	x				
Sulphide		85									
Sulphate		71, 85, 87, 94, L-74				x	x				
Chloride		71, 85, 87, 94, L-74				x	x				
Fluoride		L-74									

Parameters	AOSERP			NRBS		Syncrude 1977	Syncrude 1978; 1977	Kelly *et al.* 2010; 2009	Hazewinkel *et al.* 2008; Curtis *et al.* 2010	Colavecchia *et al.* 2004	Conly *et al.* 2007; Headley *et al.* 2001
More than 5 years of data in program											
Program/study focus	Water & Sediment	Water	Sediment	Sediment		Water	Water	Water	Water	Sediment	Sediment
Reference(s): See table below for cross reference	17 / 53	71 / 85 / 87/ 94 / L-74	34	Crosley 1996	Brownlee *et al* 1996	Aquatic Environments Ltd 1977	Aquatic Environments Ltd. 1978; 1977				
General frequency of sampling											Annually for 3 years
Silicon		71, 85					x				
Hardness		85, 94, L-74					x				
Alkalinity		71, 85, 94, L-74					x				
Bicarbonate		85, 87, 94					x				
Physicals											
Conductivity/ conductance		85, 87, 94, L-74				x	x				
pH		85, 87, 94, L-74				x	x				
Temperature		71				x	x				
Turbidity		85, 94, L-74				x	x				
TDS		85, L-74				x	x				
TSS		85, 94, L-74				x	x				
BOD											
Colour		71, 85, L-74					x				
Petroleum Hydrocarbons											
Benzene											
Toluene											
Ethylene											
Xylene											
F1 (C6-C10)											
F2 (C10-C16)											
F3 (C16-C34)											
F4 (C34-C50)											
Oil and Grease											
colourimetric		85, L-74									
gravimetric							x				
Cyanide		85									
Organics, including pesticides (see list of parameters below table)	Note 4			Note 5	Note 6						

AOSERP Report #	Citation
17	Lutz and Hendzel 1976
34	Allan and Jackson 1978
53	Strosher and Peake 1979
71	Hesslein 1979
85	Akena 1979
87	Schwartz 1980
94	Ash and Noton 1980
L-74	Akena and Christian 1981

Note 1: Alberta Environment Long-term River Network, other Organics

Organics, including pesticides, sampled at AENV LTRN sites:
12 Diphenylhydrazine, 24dimethylphenol, 24Dinitophenol, 24Dinitrotoluene, 26-Dinitrotoluene, 2-chloronaphthalene, 2-chlorophenol, 2-Methyl-46-Dinitrophenol, 2-Nitrophenol, 4-Bromophenyl, Phenyl Ether, 4-Chloro-2-Methylphenol, 4-Chloro-3-Methylphenol, 4-Chlorophenyl Phenyl Ether, 4-Nitrophenol, Bis(2-Chloroethoxy) Methane, Bis(2-Chloroeethyl) Ether, Bis(2-Chloroisopropyl) ether, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Isophorone, Nitrobenzene, N-Nitroso-Di-N-Propylamine, N-Nitrosodiphenylamine, Phenol, 1,1,1,2-tetrachloroethane, 1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethane, 1,1-Dichloroethylene, 1,1-Dichloropropylene, 1,2,3-Trichlorobenzene, 1,2,4-Trimethylbenzene, 1,2-Dibromo-3-Chloropropane, 1,2-Dibromoethane, 1,2-Dichlorobenzene, 1,2-Dichloroethane, 1,2-Dichloropropane, 1,3,5-trimethylbenzene, 1,3-Dichlorobenzene, 1,3-Dichloropropane, 2-chloroethylvinylether, 2-chloroethoxyethylene, 4-Chlorotoluene, Benzene, Bromobenzene, Dibromochloromethane, Bromoform, Bromomethane, Cis-1,2-Dichloroethane, Cis-1,3-Dichloropropene, Cresol (m, o, p), Dibromomethane, Dichlorobromomethane, Ethyl Benzene, Isopropylbenzene, M-+P-Xylene, Methy Tertiary Butyl Ether, Dichloromethan, N-Butylbenzene, N-Propylbenzene, O-Xylene, P-isopropyltoluene, Sec-Butylbenzene, Styrene, Tert-Butylbenzene, Tetrachloroenylene, Toluene, Trans-1,2-Dichlorotoethene, Trans-1,3-Dichloropropene, Trichloroethylene, Trichlorofluoromethane, Trihalomethanes, Vinyl Chloride, Xylene, 2,3,4,6-Tetrachlorophenol, 2,3,6-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichorophenol, 3,4,5-Trichlorocatecol, 3,4,5-Trichloroguaiacol, 3,4,5-trichloroveratrol, 3,4,6-Trichlorocatechol, 3,4,6-Trichloroguaiacol, 3,4-Dichlorocatechol, 3,5-Dichlorocatechol, 4,5,6-Trichloroguaiacol, 4,5,6-Trichlorosyringol, 4,5-Dichlorocatechol, 4,5-Dichloroguaiacol, 4,5-Dichloroveratrole, 4,6-Dichloroguaiacol, 4-chlorocatechol, 4-Chloroguaiacol, 4-Chlorophenol, Bromacil, Bromoxynil, Carbathiin (Carboxin), Cyanazine, Diazinon, Diclofop-Methyl (Hoegrass), Disulfoton (Di-Syston), Diuron, Chlorpyrifos-Ethyl (Dursban), Ethalfluralin (Edge), Ethion, Guthion , Clopyralid (Lontrel), Malathion, MCPA, MCPB ,MCPP (Mecoprop), Picloram (Tordon), Phorate (Thimet), Terbufos, Triallate (Avadex BW), Trifluralin (Treflan), Imazamethabenz-Methyl, Desethyl Atrazine, Desisopropyl Atrazine, Quinclorac, Imazethapyr, Fenoxaprop-P-Ethyl, Pyridaben, Dimethoate (Cygon), Pentachlorophenol, Tetrachlorocatecol, Tetrachloroguaiacol, Tetrachloroveratrol, 12,14-Dichlorodehydroabietic Acid, 12-Chlorodehydroabietic Acid, 14-Chlorodehydroabietic Acid, Abietic Acid, Dehydroabietic Acid, Isopimaric Acid, Levopimaric Acid, Neoabietic Acid, Palustric Acid, Pimaric Acid, Sandaracopimaric Acid, 2,4-D (Dichlorophenoxyacetic Acid), 2,4-DB, Dichlorprop (2,4-DP), Alpha-Benzenehexachloride (BHC), Alpha-Endosulfan, γ-Hexachlorocyclohexane (Lindane), Methoxychlor (P,P'-Methoxychlor), Atrazine, Aldrin, Dieldrin, Metolachlor, Imazamox, Parathion, Metribuzin, Dicamba, Simazine, Triclopyr, Aminopyralid, Napropamide, Thiamethoxam, Vinclozolin, Oxycarboxin, Methomyl, Aldicarb, Clodinafop-Propargyl, Clodinafop Acid Metabolite, 4-Chloro-2-Methylphenol, 2,4-Dichlorophenol, Chlorothalonil, Iprodione, Popiconazole, Hexaconazole, Metalaxyl-M, Fluazifop, Fluroxypyr, Quizalofop, Bentazon, Ethofumesate, Linuron, Adsorbable Organic Halide AOX.

Note 2:
RAMP seasonal water quality sampling is conducted for three years following site establishment and once every three years thereafter in the fall, with limited seasonal sampling for particular sites.

Note 3:

Prior to 2006, RAMP sediment sampling was conducted annually in the fall for three years following site establishment and once every three years thereafter for sites located in watersheds bearing pre-existing RAMP stations. Since 2006, sediments are sampled in conjunction with the benthic invertebrate schedule.

Note 4: AOSERP Report #53

Total organic carbon, Asphaltenes, Aliphatic hydrocarbons, Aromatic hydrocarbons, Polar compounds, Amphoteric compounds, Phenols, Organic acids, Amino acids, Sulphur compounds, Organic phosphorous compounds, Organic nitrogen compounds, Chlorinated hydrocarbons*, Chlorins, Amides, Tannins and lignins, Water soluble organic compounds.

* The detected responses of chlorinated hydrocarbons revealed distinct resolved compounds similar in character to responses obtained for a variety of pesticides; however, further examination by an electron capture detector has failed to identify them as any of the more commonly used pesticides.

Note 5: Crosley 1996

Pimaric acid, Sandaracopimaric acid, Isopimaric acid, Palustric acid, DHI, DHA, Abietic acid, Neoabeitic acid, 12/14 C1-DHA, 12,14-DiCl-DHA, Total resin acids, M1CDD, D2CDD, T3CDD, T4CDD, P5CDD, H6CDD, H7CDD, O8CDD, M1CDF, D2CDF, T3CDF, T4CDF, P5CDF, H6CDF, H7CDF, O8CDF, 4-CP, 2,6-DCP, 2,4/2,5-DCP, 3,6-DCP, 2,3-DCP, 3,4-DCP, 6-CG, 5-CG, 2,4,6-TCP, 2,3,6,-TCP, 2,3,5-TCP, 2,4,5-TCP, 2,3,4-TCP, 3,4,5-TCP, 3-CC, 4-CC, 4,6-DCG, 3,4-DCG, 4,5-DCG, 3-S, 3,6-DCG, 3,5-DCC, 3,4-DCC, 4,5-DCC, 2,3,5,6-TCP, 2,3,4,6-TCP, 2,3,4,5-TCP, 5-CV, 6-CV, 3,5,-DCS, 3,4,6-TCG, 3,4,5-TCG, 4,5,6-TCG, 3,4,6-TCC, 3,4,5-TCC, 5,6-DCV, PCP, 2-CSA, 3,4,5,6-TCG, 3,4,5-TCS, 3,4,5,6-TCC, 2,6-DCSA, Aroclor 1242, Aroclor 1254, Aroclor 1260, PCB #77, PCB#126, PCB#169, Extractable organic halogen, Toxaphene.

Note 6: Brownlee *et al.* 1996

TCDD, PeCDD, HxCDD, HpCDD, TCDF, PeCDF, HxCDF, HpCDF, 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, 1,2,3,4,6,7,8-HpCDD, OCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, OCDF, Pimeric acid, Sandaracopimaric acid, Ispimeric acid, Palustric acid, Dehydroisopimaric acid, Dehydroabietic acid, Abietic acid, Neoabietic acid, 12/14-Chlorodehydroabietic acid, 12,14-Dichloriodehydroabietic acid, 4-Chlorocatechol, 2,4,-Dichlorocatechol, 3,4,5-Trichlorocatechol, 3,4,6-Trichlorocatechol, Tetraclorocatechol, 5-Chlorovanillin, 6-Chlorovanillin, 3,4,5-Trichloroguaiacol, 3,4,5-Trichloroveratrole, 2-Chlorosyringaldehyde.

APPENDIX 2: WATER QUALITY PARAMETERS OF CONCERN FROM EIAS

Table 2.1: Water quality parameters of concern, extracted and compiled from ten oil sands open-pit mine Environmental Impact Assessments (EIAs) (Fort Hills True North 2001 through Jackpine Mine Expansion/Pierre River Mine 2007). Keys are below.

Quality Parameter of Concern	Environmental Impact Assessment(s) Reported In (Table 3)	Area(s) of Elevation* (Table 1)
Aluminum	1, 2, 3, 4, 5, 6, 10,	[37, 38, 39][17, 18, 19, 22, 23][8, 9, 12, 15, 16][7, 12, 40, 41, 42, 43][7, 10, 44, 45][1, 5, 7, 9, 10, 11, 12][33, 46]
Ammonia	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][17, 18, 20, 22, 23][1, 8, 14, 15, 16][1, 40, 43][7, 21, 44, 45][13][27, 29, 30, 31, 32, 34, 35, 37][21, 24, 25, 26][48, [46]
Antimony	1, 2, 3, 4, 5, 6, 8, 9, 10,	[38, 39][17, 18, 21][8, 9, 12, 16][7, 12, 41, 43][10, 44, 45][5, 7, 13][24, 26][48, [33, 46]
Arsenic	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 39][18, 21, 22, 23][8, 9, 12, 15, 16][7, 42, 43][7][4, 5, 7, 9][34][24, 26][48, [33, 46]
Barium	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[37, 38, 39,][17, 18, 19, 20, 22, 23][8, 9, 12, 15, 16][42][7, 10, 44, 45][9][31, 32, 34, 35, 37][24, 26][48, [33]
Beryllium	1, 2, 3, 4, 5, 6, 8, 10,	[21, 37, 38, 39][22, 23][8, 9, 12, 15, 16][11, 12, 41, 43][7, 10, 44, 45][6, 7, 8, 9, 11, 12][24, 25, 26][33, 46]
Boron	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][17, 18, 19, 20, 21, 22, 23][1, 4, 8, 9, 12, 14, 15, 16][1, 40, 42, 43][1, 7, 10, 44, 45] [1, 4, 7, 8, 9, 10, 11, 12][31, 34, 36][21, 26][48, 49][33, 46]
Cadmium	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 38, 39][17, 23][8, 9, 12, 15, 16][7, 43][7, 10, 44, 45][2, 5, 8, 9][31, 32][24, 26][33, 46]
Calcium	1, 2, 3, 4, 5, 6, 7, 10,	[21, 37, 38, 39][19, 20, 22, 23][8, 15, 16][42, 43][1, 7, 10, 45][9, 10, 11, 12][31, 33, 35, 37][33, 46]
Chloride	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][19, 20, 22, 23][8, 9, 12, 15, 16][43][10, 44, 45][1, 5, 7, 8, 9, 10, 11, 12][31, 35, 37][24, 25, 26][48, 49][33, 46]
Chromium	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][20, 22, 23][8, 9, 12, 15, 16][7, 42, 43][7, 10][5, 7, 9, 10][27, 31, 35, 37][24, 25, 26][33]

Cobalt	6,	[5, 7, 8, 9]
Conductance	1, 2,	[21, 37, 38, 39][22, 23]
Copper	1, 2, 3, 4, 5, 6, 8, 10,	[21, 37, 38, 39][18, 19, 20, 22, 23][8, 9, 12, 15, 16][7, 11, 42, 43][7, 10, 44, 45][8, 9, 10, 11][24, 25, 26][33]
Dissolved Organic Carbon	1, 2, 3, 4, 6, 7, 9, 10,	[21, 37, 38, 39][19, 20, 21][4, 8, 15, 16][42, 43][1, 7, 45][5, 9, 10, 11, 12][27, 31, 32, 33, 35, 37][48, [33, 46]
Iron	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][17, 18, 19, 20, 22, 23][8, 9, 15, 16][7, 12, 41, 42, 43] [7, 10, 44, 45][5, 9, 10][27, 29, 30, 31, 32, 33, 34][26][33, 46]
Lead	1, 2, 3, 4, 6, 8, 9, 10,	[21, 37, 38, 39][23][8, 9][43] [5][26][48, [33, 46]
Magnesium	1, 2, 3, 4, 5, 6, 7, 10,	[21, 37, 38, 39][19, 20, 22, 23][8, 9, 15, 16][42, 43][7, 10, 44, 45][9, 10, 11, 12][33, 35][33, 46]
Manganese	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][17, 18, 19, 20, 21, 22, 23][8, 9, 15, 16][1, 12, 42, 43][1, 7, 10, 44, 45][5, 9][27, 30, 31, 32, 33, 34, 35][24, 26][33]
Mercury	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][17, 18, 20, 21, 22, 23][8, 15, 16][1, 40, 42, 43][10, 44, 45][5, 9, 10, 11, 12][34, 37][25, 26][33, 46]
Molybdenum	1, 2, 3, 4, 5, 6, 8, 9, 10,	[21, 37, 38, 39][22, 23][1, 4, 9, 12, 14, 15, 16][1, 12, 40, 42, 43][1, 7, 10, 44, 45][1, 4, 5, 7, 8, 9, 10, 11, 12][21, 25, 26][48, 49][33, 46]
Monomer	1,	[21, 38]
Naphthenic Acids – Labile	6, 8,	[7, 8, 13][21, 25, 26]
Naphthenic Acids – Refractory	6, 7, 8,	[1, 3, 4, 6, 7, 8, 9, 10, 11, 12][31, 32, 33, 35][21, 24, 25, 26]
Napthenic Acids – Total	1, 2, 3, 4, 5, 6, 8, 9, 10,	[21, 37, 38, 39][18, 19, 20, 22, 23][4, 8, 12, 15, 16][43][1, 7, 10, 44, 45][1, 4, 6, 7, 8, 9, 10, 11, 12][21, 24, 25, 26][48, [33, 46, 47]

Nickel	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][18, 22, 23][4, 8, 9, 12, 15, 16][12, 41, 42, 43][7, 10, 44, 45][5, 7, 8, 9, 10, 12][31, 34, 35, 37][21, 24, 25, 26][46, [33, 46]
Nitrate + Nitrite	1,	[21, 37, 38, 39]
PAH Group 1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][19, 20, 22, 23][1, 4, 8, 9, 12, 14, 15, 16][4, 40][7, 10, 44, 45][6, 7, 8, 9, 10, 12][34][24][48, 49][33]
PAH Group 2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][17, 20, 22, 23][1, 4, 8, 9, 12, 15, 16][40, 42][1, 10, 44, 45][1, 2, 3, 6, 7, 8, 9, 10, 12][34][24, 25][48, 49][33, 46]
PAH Group 3	4,	[4]
PAH Group 4	3, 4, 6, 8, 10,	[1, 4, 8, 9, 12, 14, 15, 16][4, 40][7, 8, 10][24][33, 46]
PAH Group 5	3, 4, 6, 7, 8, 10,	[4, 8, 9, 12, 14, 15, 16][4, 11, 12, 40][3, 6, 7, 8, 9, 12][34, 37][24][33, 46]
PAH Group 6	3, 4, 6, 10,	[1, 4, 8, 9, 12, 14, 15, 16][1, 4, 40][1, 4, 8, 9, 10, 12][33, 46]
PAH Group 7	3, 4, 6, 7, 10,	[8, 9, 12, 14, 15, 16][42][3, 7, 8, 12][34, 37][33, 46]
PAH Group 8	3, 4, 6, 7, 8, 10,	[8, 9, 12, 15, 16][11, 12, 41, 42][1, 4, 7, 8][34, 37][24, 26][33, 46]
PAH Group 9	3, 4, 6, 7, 10,	[1, 8, 9, 12, 14, 15, 16][40][8, 10, 12][34, 36, 37][33, 46]
PAH (Total)	1,	[21, 37, 38, 39]
Polymer	1, 5,	[21, 37, 38, 39][10, 44, 45]
Potassium	1, 2, 6, 7,	[37, 38, 39][22][5, 7, 8, 9, 10, 12][21]
Selenium	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][19, 20, 21, 22, 23][12, 15, 16][7, 42][10, 44][5, 7, 8, 9, 10, 12][27, 34, 35, 37][26][33, 46]
Silver	2, 3, 4, 5, 6, 7, 8, 10,	[17, 18, 19, 20, 22, 23][8, 14, 15, 16][40, 43][10][5, 7][27, 31, 32, 33, 34, 35, 37][24, 26][33, 46]

Sodium	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][18, 20, 22][1, 8, 12, 14, 15, 16][42, 43][1, 10, 44, 45][1, 5, 7, 8, 9, 10, 12][35, 37][25, 26][48, 49][33, 46]
Strontium	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, 38, 39][20, 22, 23][8, 9, 12, 15, 16][42, 43][7, 10, 44, 45] [3, 7, 8, 9, 10, 12][31, 33, 34, 35][26][48, [33, 46]
Sulphate	1, 2, 3, 4, 5, 6, 8, 9, 10,	[21, 37, 38, 39][22, 23][1, 8, 9, 12, 14, 15, 16][1, 12, 42, 43][1, 7, 10, 44, 45][1, 2, 3, 4, 7, 8, 9, 10, 12][21, 25, 26][48, 49][33, 46, 47]
Sulphide	1, 2, 3, 4, 5, 7, 8, 9, 10,	[21, 37, 38, **39**][17, 18, 19, 20, **22**, **23**][8][**7**, 11, 43][1, **7**, 21, 45][27, 30, 31, 32, 33, 34,][26][48, [10]
Tainting Potential	3, 4, 5, 6, 8, 10,	[1, 4, 8, 9, 12, 14, 15,16][1, 4, 7, 11, 40, 42][1, 44][1, 7, 8, 9, 10, 12][21, 25, 26][33, 46]
Total Dissolved Solids	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, **37**, **38**, **39**][17, 18, 19, 20, 21, 22, 23][4, 8, 9, 12, 15, 16][1, 7, 10, 44, 45][40, 42 43][1, 4, 7, 8, 9, 10, 12][27, 31, 32, 33, 34, 35, 36, 37] [24, 25, 26][48, 49][33, 46, 47]
Total Nitrogen	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	[21, 37, **38**, **39**][17, 18, 19, 20, 21, **22**, 23][8, 9, **12**, **15**, **16**][**12**, **41**, 42, **43**][7, **44**][7, **8**, **9**, 10, **12**][31, 32, 33, 35, 37][26][48, [33, 46]
Total Phenolics	1, 2, 3, 4, 5, 6, 7, 8, 10,	[**38**, 39][**22**][8, 15][**7**, **11**, 12, 41, **43**][1, 7, 44][9][27, 29, 30, 31, 32, 33] [**24**, 25, 26][33, 46]
Total Phosphorus	1, 2, 3, 4, 5, 6, 8, 9, 10,	[37, **38**, 39][17, 18, 19, 20, **22**, 23][8, 9, **12**, **15**, **16**][**7**, **42**, **43**][7, 10, 44, 45][**1**, 2, **9**, 10][**24**, **25**, **26**] [**49**][33, 46]
Toxicity – Acute	1, 2, 3, 4, 5, 6, 8, 9, 10,	[21, 37, 38, 39][22][1, 4, 8, 9, 12, 15, 16][4, 11, 40, 42][7, 10, 44, 45][1, 7, 8, 9, 10][25, 26][48, 49] [21, 33, 46]
Toxicity – Chronic	1, 2, 3, 4, 5, 6, 8, 9, 10,	[21, 37, 38, 39][17, 18, 19, 20, 21, 22, 23][1, 4, 8, 9, 12, 15, 16][4, 11, 40, 41, 42][7, 44][1, 7, 8][25, 26][48, 49][33, 46]
Vanadium	1, 2, 3, 4, 5, 6, 8, 10,	[21, 37, 38, 39][17, 18, 22, 23][1, 8, 9, 12, 15, 16][42 43][7, 44][5, 7, 8, 9, 10, 12][26][33, 46]
Zinc	1, 2, 3, 4, 5, 6, 7, 8, 10,	[21, 37, 38, 39][17, 18, 19, 20, 21, 22, 23][8, 9, 12, 15, 16][7, 12, 43][1, 7, 10, 44, 45][1, 5, 9][31, 35][26][33]

*An "elevation" is here defined as an increased concentration present in the application vs. the baseline case and might occur within any given temporal reach (from present – far future). Furthermore, it is important to note here that "baseline" is to be distinguished from "pre-industrial" in that baseline conditions account for the impacts of all currently existing and approved projects prior to the proposed development (including "pre-industrial" [natural] quality levels). Elevations have been denoted as such, even if these increased concentrations were projected to later re-stabilize at/below baseline or pre-industrial levels. When both median and peak concentrations were reported, only median values were considered, except when peak values were predicted to exceed guidelines. When both annual and open flow predictions were made, only open flow values were considered. **Bold font indicates that guideline exceedances for a particular parameter are caused or exacerbated by project operations at the denoted location.**

Table 2.2: Areas of Elevation

Basin	Location	#
Athabasca River	Downstream of Muskeg River	1
	Downstream of Pierre River	2
	Downstream of Big Creek	3
	Downstream of Ells River	25
	Downstream of Embarras River	4
	Downstream of Tar River	17
	Downstream of Calumet/Athabasca Confluence	18
	Downstream of Calumet River	19
	Downstream of CNRL Horizon Diversion Channel	20
	Downstream of Firebag River	27
	Upstream of Embarras River	21
	Downstream of Isadore's Lake	40
	Downstream of Steepbank River	47
	Downstream of McLean Creek	49
Big Creek	Mouth	5
Eymundson Creek	Mouth	6
Jackpine Creek	Mouth	7
Kearl Lake	N/A	8
Muskeg River	Downstream of Headwater Tributaries	9
	Downstream of Muskeg Creek	10
	Downstream of Jackpine Creek	11
	Upstream of Jackpine Creek	41
	At EC Gauge Station	45

Basin	Location	#
	Mouth	12
Pierre River	Mouth	13
Firebag River	Downstream of Kearl Lake Tailings Seepage	14
	Upstream of Marguerite River	36
	Mouth	37
Wapasu Creek	Mouth	15
Unnamed Tributary (Muskeg River)	Mouth	16
Tar River	Mouth	22
Calumet River	Mouth	23
Joslyn Creek	Mouth	24
Ells River	Mouth	26
Reid Creek Tributary	Mouth	29
Reid Creek	Mouth	30
Audet Lake	Outlet	31
Beaver Creek	Mouth	32
Unnamed Creek	Mouth	33
Marguerite River	Mouth	34
Dencher Creek	Mouth	35
Fort Creek	Mouth	38
McClelland Lake	N/A	39
Isodore's Lake	N/A	42
Mills Creek	Mouth	43
Muskeg Creek	Mouth	44
Steepbank River	Mouth	46
McLean Creek	Mouth	48

Table 2.3: PAH group constituents

PAH Group	Constituents Included
1	dibenzo(a,h)anthracene; benzo(a)pyrene; methyl benzo(b&k)fluoroanthene/methyl benzo(a)pyrene; C2 substituted benzo(b&k)fluoroanthene/methyl benzo(a)pyrene
2	benzo(a)anthracene/chrysene; methyl benzo(a)anthracene/chrysene; C2 substituted benzo(a)anthracene/chrysene; benzo(b&k)fluoranthene; Indeno(c,d-123)pyrene
3	benzo(g,h,i)perylene; chrysene; carbazole; methyl carbazole; C2 substitued carbazole

4	acenaphthene; methyl acenaphthene; acenaphthylene
5	anthracene; phenanthrene; methyl phenanthrene/anthracene; C3 substituted phenathrene/anthracene; C4 substituted phenathrene/anthracene; 1-methyl-7-propyl phenanthrene (retene)
6	biphenyl; methyl biphenyl; C2 substituted biphenyl; C3 substituted biphenyl
7	fluoranthene;fluorene; methyl fluorene; C2 substituted fluorene
8	naphthalene; methyl napthalenes; C2 substituted napthalenes; C3 substituted napthalenes; C4 substituted napthalenes
9	Methyl fluroanthene/pyrene; pyrene

Table 2.4: Environmental Assessment reported in

#	Developer	Project	EIA	
			Volume(s)	Page(s)
1	True North Energy [now Suncor]	Fort Hills, 2001	3A; 5B	6-6 thru 683; 6.1-7 thru 6.1-20
2	CNRL	Horizon, 2002	5a; Appendix 5C	5-1 thru 5-118; C7-24 thru C7-43; C8-18 thruC8-21
3	Imperial Oil	Kearl Mine, 2005	Volume 6 - Appendices 5B; 5C; 5D	5B-1 thru 5B-12; 5D-1 thru 5D-2; 5C-1 thru 5C-11
4	Shell Canada	Muskeg River Mine Expansion, 2005	Appendix 3-8	391 thru 653
5	Shell Canada	Jackpine Mine Phase I, 2002	Surface Water Quality and Human, Aquatic Biota and Wildlife Health	2-13 thru 2-77
6	Shell Canada	Jackpine Mine Expansion / Pierre River Mine, 2007	4a; Appendix 4-7	1 thru 459; 6-403 thru 6-405
7	Synenco	Northern Lights, 2006	2007 Supplemental Information; Appendices H-3; H-5	95 thru 128; 63 thru 73; 26 thru 51
8	Deer Creek Energy [now Total]	Joslyn North Mine, 2006	2010 Additional Information; Appendix J	14-115 thru 14-132; J-40 thru J-47
9	Suncor Energy	South Tailings Pond, 2003	Volume 2	3-14 thru 3-118
10	Suncor Energy	Voyageur, 2005	Water Quality Modeling Report for the Suncor Voyageur Project	36 thru 98

APPENDIX 3: COMPOUNDS OF PARTICULAR CONCERN AND WATER QUALITY GUIDELINES

The following table contains the compounds of particular concern from Appendix 2, and water quality guidelines for those parameters (if guidelines exist), including CCME guidelines for the protection of aquatic life (freshwater), Alberta Environment Surface Water Quality Guidelines, and U.S. EPA water quality guidelines. CCME Sediment (protection of aquatic life) Quality Guidelines are also included.

Oil Sands Compounds of Specific Concern Compiled from oil sands mining project EIA reviews (Appendix 2)	CCME - Canadian Environmental Quality Guidelines (CEQG) - Summary Table http://st.ts.ccme.ca/ Chemical Name	CCME Water Quality Guidelines - Protection of Aquatic Life Freshwater Concentration (µg/L) Short Term	Concentration (µg/L) Long Term	Date	Water CCME	Alberta Environment Surface Water Quality Guidelines http://environment.alberta.ca/01323.html Concentration (µg/L) Acute	Concentration (µg/L) Chronic	Water AENV	US EPA (from AENV table, or EPA table) http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm Concentration (µg/L) Maximum Concentration	Concentration (µg/L) Continuous Concentration	Water US EPA	Sediment Quality Guidelines - Protection of Aquatic Life Freshwater Concentration (µg/kg) ISQG	Concentration (µg/kg) PEL	Date	Sediment CCME
PAH 8	2-Methylnaphthalene	No data	No data	No data	N	x - did not find		U	x - did not find		U	20.2	201	1998	Y
PAH 4	Acenaphthene	No data	5.8	1999	Y	- no AENV guide.		[illegible]	no EPA guide.		N	6.71	88.9	1998	Y
PAH 4	Acenaphthylene	No data	No data	1999	N	x - did not find		U	no EPA guide.		N	5.87	128	1998	Y
	Acridine	No data	4.4	1999	Y	- no AENV guide		N			U	No data	No data	No data	N
1 Aluminum	Aluminium	No data	Variable	1987	Y	- no AENV guide.		N	750	87	Y	No data	No data	No data	N
2 Ammonia	Ammonia (total)	No data		2001	Y			U			Y	No data	No data	No data	N
Ammonia	Ammonia (un-ionized)	No data	19	2001	Y			U			Y	No data	No data	No data	N
PAH 5	Anthracene	No data	0.012	1999	Y	- no AENV guide.		N	no EPA guide.		N	46.9	245	1998	Y
3 Antimony	Antimony	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
4 Arsenic	Arsenic	No data	5	1997	Y	- no AENV guide.		N	340	150	Y	5900	17 000	1998	Y
5 Barium	Barium	No data	No data	No data	N	x - did not find		U	no EPA guide.		N	No data	No data	No data	N
	Benzene	No data	370	1999	Y	- no AENV guide.		N			U	No data	No data	No data	N
PAH 2	Benzo(a)anthracene	No data	0.018	1999	Y	- no AENV guide.		N	no EPA guide.		N	31.7	385	1998	Y
PAH 1	Benzo(a)pyrene	No data	0.015	1999	Y	- no AENV guide.		N	no EPA guide.		N	31.9	782	1998	Y
PAH 2	Benzo(b)fluoranthene	No data	No data	No data	N	x - did not find		U	no EPA guide.		N	No data	No data	No data	N
6 Beryllium	Beryllium	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
7 Boron	Boron	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	Y	x - did not find		U	EPA: see narrative		Y	No data	No data	No data	N
8 Cadmium	Cadmium (*CCME revising)	No data	Equation	1996	Y	- no AENV guide.		N			Y	600	3500	1997	Y

Oil Sands Compounds of Specific Concern Compiled from oil sands mining project EIA reviews (Appendix 2)	CCME - Canadian Environmental Quality Guidelines (CEQG) - Summary Table http://st-ts.ccme.ca/	CCME Water Quality Guidelines - Protection of Aquatic Life Freshwater			Water	Alberta Environment Surface Water Quality Guidelines http://environment.alberta.ca/01323.html		Water	US EPA (from AENV table, or EPA table) http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm		Water	Sediment Quality Guidelines - Protection of Aquatic Life Freshwater			Sediment
		Concentration (µg/L)	Concentration (µg/L)	Date		Concentration (µg/L)	Concentration (µg/L)		Concentration (µg/L)	Concentration (µg/L)		Concentration (µg/kg)	Concentration (µg/kg)	Date	
	Chemical Name	Short Term	Long Term		CCME	Acute	Chronic	AENV	Maximum Concentration	Continuous Concentration	US EPA	ISQG	PEL		CCME
9 Calcium	Calcium	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
10 Chloride	Chloride (*CCME revising)	No data	No data	No data	N	- no AENV guide.		N	860 mg/L	230 mg/L	Y	No data	No data	No data	N
11 Chromium	Chromium (total)	No data	No data	No data	N	- no AENV guide. Lists CCME # for Chromium III and VI		N	Chromium VI - 16	Chromium VI - 11	Y	37 300	90 000	1998	Y
PAH 3	Chrysene	No data	Insufficient data	1999	N	x - did not find		U	no EPA guide.		N	57.1	862	1998	Y
12 Cobalt	Cobalt	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
13 Conductance	Conductivity	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
14 Copper	Copper	No data	Equation	1987	Y	CCME: lists 2 to 4	7	Y			Y	35 700	197 000	1998	Y
PAH 1	Dibenz(a,h)anthracene	No data	No data	No data	N	x - did not find		U	no EPA guide.		N	6.22	135	1998	Y
15 Dissolved Organic Carbon					U	x - did not find		U	x - did not find		U				U
PAH 7	Fluoranthene	No data	0.04	1999	Y	- no AENV guide.		N	no EPA guide.		N	111	2355	1998	Y
PAH 7	Fluorene	No data	3	1999	Y	- no AENV guide.		N	no EPA guide.		N	21.2	144	1998	Y
PAH 2	Indeno(1,2,3-c,d)pyrene	No data	No data	No data	N	x - did not find		U	no EPA guide.		N	No data	No data	No data	N
16 Iron	Iron	No data	300	1987	Y	- no AENV guide.		N		1000	Y	No data	No data	No data	N
17 Lead	Lead	No data	Equation	1987	Y	- no AENV guide. CCME: 1 to 7		N			Y	35 000	91 3000	1998	Y
18 Magnesium	Magnesium				U	x - did not find		U	x - did not find		U				U
19 Manganese	Manganese	No data	No data	No data	N	x - did not find		U	no EPA guide.		N	No data	No data	No data	N
20 Mercury	Mercury	No data	No data	No data	N	AENV: Total 0.13 ; methyl 0.002. CCME: Total 0.1 (Acute)	AENV: Total 0.005 ; methyl 0.001 CCME: Total 0.1	Y	1.4	0.77	Y	170	486	1997	Y

Oil Sands Compounds of Specific Concern	CCME - Canadian Environmental Quality Guidelines (CEQG) - Summary Table	CCME Water Quality Guidelines - Protection of Aquatic Life			Water	Alberta Environment		Water	US EPA (from AENV table, or EPA table)		Water	Sediment Quality Guidelines - Protection of Aquatic Life			Sediment
	http://st-ts.ccme.ca/	Freshwater				Surface Water Quality Guidelines						Freshwater			
		-	-	-		http://environment.alberta.ca/01323.html			http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm						
Compiled from oil sands mining project EIA reviews (Appendix 2)		Concentration (µg/L)	Concentration (µg/L)	Date		Concentration (µg/L)	Concentration (µg/L)		Concentration (µg/L)	Concentration (µg/L)		Concentration (µg/kg)	Concentration (µg/kg)	Date	
	Chemical Name	Short Term	Long Term		CCME	Acute	Chronic	AENV	Maximum Concentration	Continuous Concentration	US EPA	ISQG	PEL		CCME
21 Molybdenum	Molybdenum	No data	73	1999	Y	- no AENV guide.		N			U	No data	No data	No data	N
23 Naphthenic Acids – Labile	Naphthalene	No data	1.1	1999	Y	- no AENV guide.		N	no EPA guide.		N	34.6	391	1998	Y
24 Naphthenic Acids – Refractory					U			U			U				U
25 Naphthenic Acids – Total					U			U			U				U
26 Nickel	Nickel	No data	Equation	1987	Y	- no AENV guide. . CCME: 25 to 150		N			Y	No data	No data	No data	N
27 Nitrate + Nitrite	Nitrate + Nitrite (*CCME revising Nitrate)	No data	No data	No data	N	AENV: listed separately. No AENV guide. CCME: Nitrite 0.06 mg/L		N	no EPA guide. (for Nitrates)		N	No data	No data	No data	N
PAH 5	Phenanthrene	No data	0.4	1999	Y	- no AENV guide.		N			U	41.9	515	1998	Y
PAH 9	Pyrene	No data	0.025	1999	Y	- no AENV guide.		N	no EPA guide.		N	53	875	1998	Y
	Quinoline	No data	3.4	1999	Y	- no AENV guide.		N			U	No data	No data	No data	N
39 Potassium	Potassium				U	x - did not find		U	x - did not find		U				U
40 Selenium	Selenium	No data	1	1987	Y	- no AENV guide.		N		5	Y	No data	No data	No data	N
41 Silver (*CCME revising)	Silver (*CCME revising)	No data	0.1	1987	Y	- no AENV guide.		N			Y	No data	No data	No data	N
42 Sodium	Sodium	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
Sodium	Sodium adsorption ratio	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
43 Strontium	Strontium				U	x - did not find		U	x - did not find		U				U
44 Sulphate	Sulphate	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
45 Sulphide	Sulphide (asH2S)	No data	No data	No data	N	- no AENV guide.		N		2	Y	No data	No data	No data	N

	Oil Sands Compounds of Specific Concern Compiled from oil sands mining project EIA reviews (Appendix 2)	CCME - Canadian Environmental Quality Guidelines (CEQG) - Summary Table http://st-ts.ccme.ca/	CCME Water Quality Guidelines - Protection of Aquatic Life Freshwater			Water	Alberta Environment Surface Water Quality Guidelines http://environment.alberta.ca/01323.html		Water	US EPA (from AENV table, or EPA table) http://water.epa.gov/scitech/swguidance/waterquality/standards/current/index.cfm		Water	Sediment Quality Guidelines - Protection of Aquatic Life Freshwater			Sediment
		Chemical Name	Concentration (µg/L) Short Term	Concentration (µg/L) Long Term	Date	CCME	Concentration (µg/L) Acute	Concentration (µg/L) Chronic	AENV	Concentration (µg/L) Maximum Concentration	Concentration (µg/L) Continuous Concentration	US EPA	Concentration (µg/kg) ISQG	Concentration (µg/kg) PEL	Date	CCME
46	Tainting Potential					U	x - did not find		U	x - did not find		U				U
47	Total Dissolved Solids	Total dissolved solids (salinity)	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
48	Total Nitrogen					U		1 mg/L	Y			U				U
49	Total Phenolics					U		5	Y	no EPA guide (for Phenol)		N				U
50	Total Phosphorus					U		0.05 mg/L	Y	no EPA guide (for Phosphorus Elemental)		N				U
N	Toxicity – Acute					U	x - did not find		U	x - did not find		U				U
52	Toxicity – Chronic					U	x - did not find		U	x - did not find		U				U
53	Vanadium	Vanadium	No data	No data	No data	N	x - did not find		U	x - did not find		U	No data	No data	No data	N
54	Zinc	Zinc (*CCME revising)	No data	30	1987	Y	- no AENV guide		N			Y	123 000	315 000	1998	Y

APPENDIX 4: ALBERTA EPEA APPROVALS OUTFALL SUMMARY TABLE

Mine	Suncor Fort Hills					Suncor Steepbank Millenium				
	Site					Site				
Parameter	Pond 1	Pond 2	Pond 4	Pond 14	Pond NNLL	Pond R	Pond A	McLean Creek	Pond 7	Pond 6
Flow (in cubic meters/day)	daily	daily	daily	daily	daily	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release
Floatable Solids, Visible Foam, Oil or Other Substance										
pH	3 per week	3 per week	3 per week	3 per week	3 per week	Daily, during discharge	Daily, during discharge	Daily, during discharge	Daily, during discharge	Daily, during discharge
Total Suspended Solids (in mg/L)	3 per week	3 per week	3 per week	3 per week	3 per week	Daily during discharge	Daily during discharge	Daily during discharge	Daily during discharge	Daily during discharge
Total Dissolved Organic Carbon (mg/L)	Once/Month	Once/Month	Once/Month	Once/Month	Once/Month					
Phenols										
Chemical Oxygen Demand						daily, during discharge	daily, during discharge	daily, during discharge	daily, during discharge	daily, during discharge
Total dissolved Iron (in mg/L)	Once/Month	Once/Month	Once/Month	Once/Month	Once/Month					
Total dissolved Manganese (in mg/L)	Once/Month	Once/Month	Once/Month	Once/Month	Once/Month					
Nutrients, major ions, DOC, DIC						weekly	weekly	weekly	weekly	weekly
5 day Biochemical Oxygen Demand	1 per week	1 per week	1 per week	1 per week	1 per week					
TR/TD metals, Hg ultra						weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
CCME F1-3										
Ammonia-Nitrogen (in mg/L)	1 per week	1 per week	1 per week	1 per week	1 per week					
Dissolved Oxygen (in mg/L)										
Chronic bioassay	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year					
96 Acute	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	Every two months	Every two months	Every two months	Every two months	Every two months
CCME F1-4										
Oil and Grease						daily, during discharge	daily, during discharge	daily, during discharge	daily, during discharge	daily, during discharge
48-Hour Static Acute Lethality Test Using *Daphnia magna*	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly					
Inorganic CCME	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year					
FULL SUITE	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year	Once per Quarter year					
Sulphide										
Priority pollutant hydrocarbons						weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
Temperature										

Mine	Suncor Base Mine				
	Site				
Parameter	Weir 10	Weir 7	Weir 1	Pond C	Pond E
Flow (in cubic meters/day)	daily, during release	daily, during release	daily, during release	daily	twice per day, during release of any cooling water
Floatable Solids, Visible Foam, Oil or Other Substance					
pH	Daily, during discharge	Daily, during discharge	Daily, during discharge	daily	Daily, during release
Total Suspended Solids (in mg/L)	Daily during discharge	Daily during discharge	Daily during discharge	3x/ week (min 2 days between samples)	daily, during release
Total Dissolved Organic Carbon (mg/L)					
Phenols				3x/ week (min 2 days between samples)	
Chemical Oxygen Demand	daily, during discharge	daily, during discharge	daily, during discharge	3x/ week (min 2 days between samples)	daily, during release
Total dissolved Iron (in mg/L)					
Total dissolved Manganese (in mg/L)					
Nutrients, major ions, DOC, DIC	weekly	weekly	weekly	weekly	weekly, during release
5 day Biochemical Oxygen Demand					
TR/TD metals, Hg ultra	weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
CCME F1-3					
Ammonia-Nitrogen (in mg/L)				weekly	
Dissolved Oxygen (in mg/L)					
Chronic bioassay	every two months	every two months	every two months	every two months, during release	every two months, during release
96 Acute	Every two months	Every two months	Every two months	Every two months, during release	Every two months, during release
CCME F1-4					
Oil and Grease	daily, during discharge	daily, during discharge	daily, during discharge	3x/ week (min 2 days between samples)	daily, during release
48-Hour Static Acute Lethality Test Using *Daphnia magna*					
Inorganic CCME					
FULL SUITE					
Sulphide				weekly	
Priority pollutant hydrocarbons	weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
Temperature					daily, during release

Mine	Imperial Oil Kearl					
	Site					
Parameter	Pond 1	Pond 2	Pond 3A	PDP	Overburden Pond (Single release)	Compensation Lake
Flow (in cubic meters/day)	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release
Floatable Solids, Visible Foam, Oil or Other Substance				weekly, during release (visual observation)		once per year, during release
pH	3 per week, during release	3 per week, during release	3 per week, during release	monthly, during release	3 per week, during release	once per year, during release
Total Suspended Solids (in mg/L)	3 per week, during release	3 per week, during release	3 per week, during release	monthly, during release	3 per week, during release	once per year, during release
Total Dissolved Organic Carbon (mg/L)						
Phenols						
Chemical Oxygen Demand						
Total dissolved Iron (in mg/L)						
Total dissolved Manganese (in mg/L)						
Nutrients, major ions, DOC, DIC	weekly, during release	weekly, during release	weekly, during release	quarterly, during release	weekly, during release	once per year, during release
5 day Biochemical Oxygen Demand	weekly, during release	weekly, during release	weekly, during release		weekly, during release	
TR/TD metals, Hg ultra	monthly	monthly	monthly	quarterly, during release	monthly	once per year, during release
CCME F1-3						
Ammonia-Nitrogen (in mg/L)	weekly, during release	weekly, during release	weekly, during release	quarterly, during release	weekly, during release	once per year, during release
Dissolved Oxygen (in mg/L)	3 per week, during release (october 1 to march 31 only)	3 per week, during release (october 1 to march 31 only)	3 per week, during release (october 1 to march 31 only)	monthly, during release (october 1 to march 31 only)	3 per week, during release (october 1 to march 31 only)	
Chronic bioassay	every two months	every two months	every two months		every two months	
96 Acute	monthly	monthly	monthly		monthly	
CCME F1-4	monthly	monthly	monthly	quarterly, during release	monthly	once per year, during release
Oil and Grease						
48-Hour Static Acute Lethality Test Using *Daphnia magna*						
Inorganic CCME						
FULL SUITE						
Sulphide						
Priority pollutant hydrocarbons						
Temperature						

Mine	Albian/Shell Jackpine				CNRL Horizon	
	Site				Site	
Parameter	Pond 2	Pond 3	Pond 4	Pond 6	Sedimentation Pond	Sedimentation Pond DD7
Flow (in cubic meters/day)						
Floatable Solids, Visible Foam, Oil or Other Substance						
pH	3 per week	3 per week	3 per week	3 per week	3 per week	3 per week
Total Suspended Solids (in mg/L)	3 per week	3 per week	3 per week	3 per week	3 per week	3 per week
Total Dissolved Organic Carbon (mg/L)	Once/Month	Once/Month	Once/Month	Once/Month	Once/Month	Once/Month
Phenols						
Chemical Oxygen Demand						
Total dissolved Iron (in mg/L)						
Total dissolved Manganese (in mg/L)						
Nutrients, major ions, DOC, DIC						
5 day Biochemical Oxygen Demand						
TR/TD metals, Hg ultra						
CCME F1-3						
Ammonia-Nitrogen (in mg/L)						
Dissolved Oxygen (in mg/L)						
Chronic bioassay	once per year	once per year	once per year	once per year	once per year	once per year
96 Acute	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly
CCME F1-4						
Oil and Grease	3 per week	3 per week	3 per week	3 per week	3 per week	3 per week
48-Hour Static Acute Lethality Test Using *Daphnia magna*	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly	monthly then quarterly
Inorganic CCME	quarterly	quarterly	quarterly	quarterly	once per year	once per year
FULL SUITE	quarterly	quarterly	quarterly	quarterly	once per year	once per year
Sulphide						
Priority pollutant hydrocarbons						
Temperature						

Mine	Suncor Voyageur			Syncrude Aurora North				
	Site			Site				
Parameter	Pond 1 (east)	Pond 2 (west)	Pond 3 (permanent)	Puhalski pond	1-05 pond	WID discharge	Diversion Inlet	Diversion Outlet
Flow (in cubic meters/day)	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release	daily, during release
Floatable Solids, Visible Foam, Oil or Other Substance								
pH	Daily, during discharge	Daily, during discharge	Daily, during discharge	Daily, work week	Daily, work week	Daily, work week	Daily, work week	Daily, work week
Total Suspended Solids (in mg/L)	Daily during discharge	Daily during discharge	Daily during discharge	Daily, work week	Daily, work week	Daily, work week	Daily, work week	Daily, work week
Total Dissolved Organic Carbon (mg/L)								
Phenols								
Chemical Oxygen Demand	daily, during discharge	daily, during discharge	daily, during discharge					
Total dissolved Iron (in mg/L)								
Total dissolved Manganese (in mg/L)								
Nutrients, major ions, DOC, DIC	weekly	weekly	weekly	weekly	weekly	weekly	weekly	weekly
5 day Biochemical Oxygen Demand				weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
TR/TD metals, Hg ultra	weekly, during release	weekly, during release	weekly, during release	monthly	monthly	monthly	monthly	monthly
CCME F1-3				monthly	monthly	monthly	monthly	monthly
Ammonia-Nitrogen (in mg/L)				weekly, during release	weekly, during release	weekly, during release	weekly, during release	weekly, during release
Dissolved Oxygen (in mg/L)				weekly, during release (October - March)	weekly, during release (October - March)	weekly, during release (October - March)	weekly, during release (October - March)	weekly, during release (October - March)
Chronic bioassay	every two months	every two months	every two months	Every two months	Every two months	Every two months	Every two months	Every two months
96 Acute	Every two months	Every two months	Every two months	monthly	monthly	monthly	monthly	monthly
CCME F1-4								
Oil and Grease	daily, during discharge	daily, during discharge	daily, during discharge					
48-Hour Static Acute Lethality Test Using *Daphnia magna*								
Inorganic CCME								
FULL SUITE								
Sulphide								
Priority pollutant hydrocarbons	weekly, during release	weekly, during release	weekly, during release					
Temperature								

Parameter and frequency Contractions for EPEA Approvals Table:

Quarterly: Once every quarter year

Major ions: Major cations and anions

Td: Total dissolved

Bold contractions, below, are parameter suites.

TR/TD metals, Hg-ultra: Total recoverable and dissolved metals, and ultra-trace mercury

CCME F1-3: CCME f1, f2, f3 hydrocarbons (characterize napthenic acids and PAHs if detected in f1-f3) report uncorrected

Chronic bioassay: Chronic lethality test using *Ceriodaphnia* and fathead minnows (including Microtox IC metric)

96 Acute: 96-hour multiple concentration acute lethality test using rainbow trout (*Oncorhyncus mykiss*)

Monthly for 1 year, quarterly thereafter: 1 per month (for 1 year), 1 per quarter year (thereafter)

CCME F1-4: CCME f1, f2, f3 & f4 hydrocarbons (characterize naphthenic acids and PAHs)

Inorganic CCME: All inorganic parameters, except chlorine and nitrosamines, listed in the guidelines for freshwater aquatic life of the Canadian Water Quality Guidelines (1988) as amended

FULL SUITE: biological oxygen demand, dissolved organic carbon, benzene, toluene, ethyl benzene, xylene (BTEX), chemical oxygen demand, chloride, colour, naphthenic acids, oil & grease, phenols, polyaromatic hydrocarbons, sulphate, total phosphorous, total dissolved solids, temperature, total sulfide, total suspended solids.

www.ec.gc.ca

Additional information can be obtained at:

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